THE CONCRETE INSTITUTE

AN INSTITUTION FOR STRUCTURAL ENGINEERS, ARCHITECTS, ETC.

TRANSACTIONS AND NOTES

INDEX

TO

VOLUME IV.

PUBLISHED AT THE OFFICES OF
THE CONCRETE INSTITUTE
DENISON HOUSE, 296, VAUXHALL BRIDGE ROAD, WESTMINSTER.

INDEX TO VOL. IV.

UNWIN BROTHERS, LIMITED, THE GRESHAM PRESS, WOKING AND LONDON

NOTES

MEMBERSHIP.

On January 31, 1912, the Institute had 934 Members, 15 Students, and 11 Special Subscribers.

DECEASED MEMBERS.

The deaths are recorded with regret of Mr. M. G. Bradford, Assoc.M.Inst.C.E. (Kmark, Kuching, Sarawak, Borneo); and Mr. T. D. Smythe, M.Inst.C.E. (Chief Engineer, Chilian State Railways, Santiago, Chile).

MEETINGS.

The Nineteenth Ordinary General Meeting was held on October 26, 1911, Sir Henry Tanner, C.B., I.S.O. (President), in the Chair.

The Twentieth Ordinary General Meeting was held on November 9, 1911, Sir Henry Tanner, C.B., I.S.O. (President), in the Chair.

The Twenty-first Ordinary General Meeting was held on December 14, 1911, Sir Henry Tanner, C.B., I.S.O. (President), in the Chair.

The Twenty-second Ordinary General Meeting was held on January 11, 1912, Mr. F. E. Wentworth-Sheilds, M.Inst.C.E. (Vice-President), in the Chair.

The Twenty-seventh Meeting of the Council was held on October 26, 1911, Sir Henry Tanner, C.B., I.S.O. (President), in the Chair.

The Twentieth-eighth Meeting of the Council was held on November 9, 1911, Sir Henry Tanner, C.B., I.S.O. (President), in the Chair.

The Twenty-ninth Meeting of the Council was held on December 14, 1911, Sir Henry Tanner, C.B., I.S.O. (President), in the Chair.

The Thirtieth Meeting of the Council was held on January 11, 1912, Sir Henry Tanner, C.B., I.S.O. (President), in the Chair.

The Ninth Meeting of the Finance and General Purposes Committee was held on October 26, 1911, Mr. E. P. Wells, J.P., in the Chair.

The Tenth Meeting of the Finance and General Purposes Committee was held on November 9, 1911, Mr. E. P. Wells, J.P., in the Chair.

The Eleventh Meeting of the Finance and General Purposes Committee was held on December 14, 1911, Mr. E. P. Wells, J.P., in the Chair.

The Twelfth Meeting of the Finance and General Purposes Committee was held on January 11, 1912, Mr. E. P. Wells, J.P., in the Chair.

The Seventh Joint Meeting of the Science and Reinforced Concrete Practice Standing Committees was held on December 28, 1911, Professor Henry Adams, M.Inst.C.E., in the Chair.

The Eighth Joint Meeting of the Science and Reinforced Concrete Practice Standing Committees was held on January 4, 1912, Professor Henry Adams, M.Inst.C.E., in the Chair.

The Ninth Joint Meeting of the Science and Reinforced Concrete Practice Standing Committees was held on January 12, 1912, Professor Henry Adams, M.Inst.C.E., in the Chair.

The Tenth Joint Meeting of the Science and Reinforced Concrete Practice Standing Committees was held on January 19, 1912, Professor Henry Adams, M.Inst.C.E., in the Chair.

The Eleventh Joint Meeting of the Science and Reinforced Concrete Practice Standing Committees was held on January 26, 1912, Professor Henry Adams, M.Inst.C.E., in the Chair.

The Twenty-second Meeting of the Science Standing Committee was held on November 30, 1911, Professor Henry Adams, M.Inst.C.E., in the Chair.

The Tenth Meeting of the Reinforced Concrete Practice Standing Committee was held on December 7, 1911, Mr. E. P. Wells, J.P., in the Chair.

The Eleventh Meeting of the Reinforced Concrete Practice Standing Committee was held on December 21, 1911, Mr. E. P. Wells, J.P., in the Chair.

The Sixth Meeting of the Tests Standing Committee was held on November 23, 1911, Mr. W. G. Kirkaldy, Assoc.M.Inst.C.E., in the Chair.

The Seventh Meeting of the Tests Standing Committee was held on January 4, 1912, Mr. E. P. Wells, J.P., in the Chair.

ACCESSIONS TO THE LIBRARY.

DONATIONS.

RECENT PUBLICATIONS PRESENTED BY THE AUTHORS.

(1) "Reinforced Concrete Construction." By Henry Adams, M.Inst.C.E., M.I.Mech.E., F.S.I., F.R.San.I., and Mr. Ernest R. Matthews, Assoc.M.Inst.C.E., F.R.S.(Ed.), F.R.San.I., F.G.S. Published by Longmans, Green & Co., 39, Paternoster Row, London. Price 10s. 6d.

Contents.

History of "Reinforced Concrete"—General Principles of Stress—Moments of Resistance, Loads and Reinforcement—Notation, Formulæ and Examples—Special Constructions—Effects of Excessive Heat on Concrete and Reinforced Concrete—Reinforced Concrete in Municipal Engineering Work—Reinforced Concrete in Railway Engineering—Reinforced Concrete in Wharves, Jetties, Groynes, Sea Walls, Bins, Fac-

tories, and other Engineering Works—Reinforced Concrete in Building Construction—General Notes.

The Preface states that although the word "theory" is used in the title, the authors have intentionally avoided all pure theory, and have included only those theoretical principles which are needed to enable the necessary calculations in the practical designing of such work to be understood. The formulæ have been reduced to the simplest conditions, and worked examples are given so that the merest tyro in mathematics will have no difficulty in utilising them. The illustrations, which are very numerous, are grouped under the various branches of construction so that any one interested in a particular subject can study a variety of typical forms. Many of the illustrations are published for the first time. Although there are other books dealing with both the theory and practice of reinforced concrete construction, there is none, the authors state, that takes it quite in the same way, and the authors trust that the facility this offers for practical use will be found one of its chief recommendations.

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(2) "Reinforced Concrete Compression Member Diagram." By Charles F. Marsh, M.Inst.C.E., M.Am.Soc.E., M.Inst.M.E. Published by Archibald Constable & Co., Haymarket, London, S.W. Price 3s. 6d.

This consists of several graphs grouped together to enable the calculations for the design of hooped pillars to be readily performed and the necessary dimensions ascertained according to the formulæ put forward in the Second Report of the Joint Committee on Reinforced Concrete appointed by the Royal Institute of British Architects, which rules have also been adopted in the regulations for the erection of buildings of reinforced concrete in London as drafted by the London County Council.

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(3) "Tonindustrie Kalender" for 1912. Published by the Tonindustrie Zeitung, Berlin.

This consists of three parts. Part I. is cloth bound, and consists of a Diary with an index of articles. Part II. is in paper covers, and contains various

tables and memoranda. Part III., also in paper covers, consists of addresses of firms and other persons, and lists of books published in Germany classified under various headings.

---

(4) The London Building Acts, 1894 to 1909: Skeleton Frame Buildings (L.C.C. General Powers Act, 1909. Part IV.): Deposit of Drawings and Calculations with the District Surveyor. Published on behalf of the District Surveyors Association by Merritt and Hatcher, Ltd., 2, Grocers' Hall Court, Poultry, London, E.C. Price 2s. 6d. net.

This book contains detailed instructions, tables, and diagrams drawn up by the District Surveyors Association, in co-operation with the Royal Institute of British Architects and the Surveyors Institution with the object that the scheme may be adopted by persons depositing with the District Surveyor plans, sections, and calculations of steel-frame structures to be erected under the provisions of the Act of 1909, as it will manifestly be convenient alike to the architect, engineer, and district surveyor, for calculations to be submitted upon a uniform basis, thus greatly reducing the labour of making and checking the calculations.

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(5) "Versuche mit Eisenbeton-Balken zur ermittlung der Wiederstandsfähigkeit Verschiedener Bewehrung gegen Schubkräfte." 2nd Part. By Professors C. Bach and O. Graf. Published by Wilhelm Ernst & Son, Berlin.

EARLIER PUBLICATIONS.

Presented by Mr. Edwin O. Sachs, F.R.S.Ed., Vice-President C.I.

Proceedings of the American Waterworks Association for the years 1906, 1907, 1908, and 1909.

Presented by Indented Bar and Concrete Engineering Company, Ltd.

The Indented Bar Bulletin. Vol. I. August, 1911.

Presented by Bureau of Standards, Washington, U.S.A.

Paper by Rudolph J. Wig, Associate Engineer-Physicist, on "The Effect of High-Pressure Steam on the Crushing Strength of Portland Cement, Mortar, and Concrete."

Presented by the author, Mr. John Stephen Sewell, M.Am.Soc.C.E.

Papers on "The Economical Design of Reinforced Concrete Floor Systems for Fire-resisting Structures," and "The Web Reinforcement of Concrete Beams." Also, Reports on the San Francisco Earthquake and Fire of April 18, 1906, by Messrs. Grove Karl Gilbert, Richard Lewis Humphrey, John Stephen Sewell, and Frank Soulé.

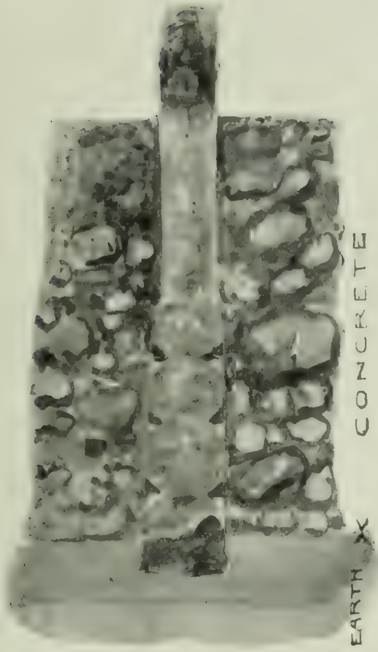
Presented by the University of Illinois.

Pamphlet entitled, "Tests of Nickel-Steel Riveted Producer," by Messrs. C. M. Garland and A. P. Kratz.

Pamphlet entitled, "Tests of Nickel-Steel Riveted Joints," by Messrs. Arthur N. Talbot and Herbert F. Moore.

Presented by Messrs. The British Reinforced Concrete Engineering Company, Ltd.

Several copies of 1911 edition of Catalogue.



Sketch showing the position of Iron Rag Bolt
found at South Kensington, London.

IRON PRESERVED IN CONCRETE.

The accompanying illustration is reproduced from a sketch sent to the Concrete Institute, together with the bolt itself, by Messrs. William King & Son, builders, of 3, Vauxhall Bridge Road, Westminster, S.W.

This rag bolt was found, in the summer of 1911, embedded in a slab of concrete composed of Portland cement, ballast, and broken bricks, in the position shown on sketch. The concrete formed part of the foundations of the 1862 Exhibition buildings at South Kensington, and had not been disturbed up to the time of its removal. The bolt was found when cutting through the concrete slab for some alteration in connection with the Imperial Institute, and was at ground-level. A floor had been constructed about 2 ft. above this level, so that the concrete and bolt were under cover. The bolt sent was one of many found, and it was thought they had bolted down machinery. Only the top end where exposed to air and the bottom end where embedded in soil were corroded ; the remainder was quite clean, with the original blue scale thereon.

ERRATA.

VOLUME III.

It should have been noted on page 273 that among the members attending the Annual Dinner on June 7, 1911, was Mr. E. P. WELLS, J.P.

On page 252, in the second line from the bottom, "Chedame" should be spelt "Chedanne."

THE CONCRETE INSTITUTE

(*FOUNDED* 1908. *INCORPORATED* 1909)

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NOTES

VOLUME IV PART II

PUBLISHED JULY, 1912
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a*

OBJECTS OF THE INSTITUTE.

The objects of the Institute are :—

(a) To advance the knowledge of concrete and reinforced concrete, and other materials employed in structural engineering, and to direct attention to the uses to which these materials can be best applied.

(b) To afford the means of communication between persons engaged in the design, supervision and execution of structural engineering works (excluding all questions connected with wages and trade regulation).

(c) To arrange periodical meetings for the purpose of discussing practical and scientific questions bearing upon the application and use of concrete and reinforced concrete and other materials employed in structural engineering for any purpose whatsoever.

The Institute is not responsible for the views of individual authors as expressed in Papers, Letters or Notes, but only for such observations as are formally issued on behalf of the Council.

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Mr. A. Alban H. Scott, M.S.A., *Hon. Secretary.*

CONTENTS

NOTES

MEMBERSHIP.

On June 30, 1912, the Institute had 878 Members, 23 Students, and 9 Special Subscribers.

DECEASED MEMBER.

Mr. William James Watson, J.P., M.R.A.I., F.S.I., Bevenue, Rostrevor, Co. Down.

ACCESSIONS TO THE LIBRARY.

DONATIONS.

RECENT PUBLICATIONS PRESENTED BY THE AUTHORS AND PUBLISHERS.

(1) "Reinforced Concrete Buildings." By Mr. Ernest L. Ransome, Assoc.Am.Soc.E., Charter Member W.Soc.E., Hon. Corres. Member R.I.A., Member Royal Society of Arts, etc., and Mr. Alexis Saurbrey, Assoc.M.Am.Soc.C.E., Member Dansk Ingeniör Forening, etc. Published by the McGraw-Hill Book Company, 6, Bouverie Street, London, E.C.

(2) "Elementary Principles of Reinforced Concrete Construction." By Mr. Ewart S. Andrews, B.Sc.Eng.(Lond.). Published by Scott, Greenwood & Son, 8, Broadway Ludgate, E.C.

(3) "Versuche über die Widerstandsfahigkeit von Beton und Eisenbeton gegen Verdrehung." By Professors C. Bach and O. Graf. Published by Wilhelm Ernst & Sohn, Berlin.

(4) "Prüfung von Balken zu Kontrollversuchen." By Professors C. Bach and O. Graf. Published by Wilhelm Ernst & Sohn, Berlin.

(5) "Untersuchungen an durch laufenden Eisenbetonkonstruktionen." With 52 illustrations. By Professors H. Scheit and E. Probst. Published by Julius Springer, Berlin.

Presented by the Author, Monsieur le Chatelier, Paris.

(1) Two pamphlets entitled "Décomposition des Ciments à la Mer."
(2) One pamphlet entitled "L'Industrie des Produits Hydrauliques dans ses Rapports avec la Science."
(3) One copy "Essais des Materiaux Hydrauliques."
(4) Chronique, "Appareil Hydrauliques."
(5) One pamphlet entitled "Tests of Hydraulic Materials." In English.
(6) One pamphlet entitled "L'Industrie des Ciments et des chaux Hydrauliques devant les Consommateurs."
(7) Six small pamphlets on various subjects.

Presented by the Paint and Varnish Society.

Paper entitled "The Protection and Finishing of Concrete Surfaces." By Mr. Robert Cathcart, Cleveland, Ohio, U.S.A.

Presented by the Author, Mr. H. St. George Robinson.

Paper entitled "The Lateral Pressure of Liquid Concrete."

Presented by the Author, Mr. J. Richard Gwyther, M.A.

Four copies of a paper entitled "The Modes of Rupture of an Open Hemispherical Concrete Shell under Axial Pressure."

Presented by the British Ceresit Water Proofing Company, Ltd.

Seven pamphlets entitled "Ceresit and its Uses in all Building Operations."

Presented by the University of Illinois.

Several copies of pamphlets entitled :—

(1) "Tests on Columns, etc." By Messrs. Arthur N. Talbot and A. R. Lord.

(2) "Starting Currents of Transformers." By Mr. Trygoe de Yensen.

(3) "Mechanical Stresses in Transmission Lines." By Mr. A. Guell.

(4) "An Investigation of the Strength of Rolled Zinc." By Mr. Herbert F. Moore.

(5) "Street Lighting." By Messrs. J. M. Bryant and H. C. Hake.

(6) "Inductance of Coils." By Messrs. Morgan Brooks and H. M. Turner.

Presented by the American Society of Mechanical Engineers.

Copies of Proceedings of the Society for December, 1911, January, 1912, February, 1912, March, 1912, April, 1912, and May, 1912.

Presented by the Liverpool Engineering Society.

Copy of the Proceedings of the Society for the 1910-11 Session.

Presented by the Engineers' Society of Western Pennsylvania.

Copies of the Proceedings of the Society for December, 1911, January, 1912, February, 1912, March, 1912, and April, 1912.

Presented by the Cleveland Engineering Society, Cleveland, Ohio.

Copy of Transactions for 1908 and copies of the Journal for September and December, 1909, March, June, September, and December, 1910, March, June, September, and December, 1911.

Presented by the Executive Committee of the Permanent International Association of Road Congresses.

(1) List of Members.
(2) Copy of Bulletin for March, 1912.

Presented by the Executive Committee of the Twelfth International Congress of Navigation, Philadelphia.

Copy of February, 1912, Bulletin.
List of Members.
Four bound volumes of papers contributed to Sections I. and II. of the Twelfth International Congress of Navigation, Philadelphia.

The following Journals are also sent gratuitously by the Publishers:—

"The Architect."
"The Builder."
"Cement-Age."
"Concrete and Constructional Engineering."
"Engineering."
"Engineering News."
"Engineering Record."
"Ferro-Concrete."
"The Indented Bar Bulletin."
"Page's Weekly."
"Southern Builder and Engineer."
"The Surveyor."
"Tonindustriè-Zeitung."

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VOLUME IV: PART III

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MEMBERSHIP.

On December 12, 1912, the Institute had 906 Members, 34 Students, and 7 Special Subscribers.

ACCESSIONS TO THE LIBRARY.

DONATIONS.

Recent Publications Presented by the Authors and Publishers.

(1) "Reinforced Concrete Construction." Vol. I. By George A. Hool, S.B., Associate Professor of Structural Engineering at the University of Wisconsin. Published by the McGraw-Hill Book Company, 6, Bouverie Street, London, E.C.

(2) "Concrete Steel Construction." Part I. By C. A. P. Turner, M.Am.Soc.C.E., Consulting Engineer. Published by the Farnham Printing and Stationery Company, Minneapolis, Minnesota.

(3) Pamphlet: "The Turner Mushroom System." By C. A. P. Turner, M.Am.Soc.C.E.

(4) "Estimating for Reinforced Concrete." By Major T. E. Coleman, Staff for Royal Engineer Services. Published by B. T. Batsford, 94, High Holborn, W.C.

Presented by the Authors, Professor C. Bach and O. Graf.

(1) Versuche mit Eisenbetonbalken zur Ermittlung Widerstandsfähigkeit Verschiedener Bewehrung gegen Schubkräfte (Dritle Teil).
(2) Mitteilungen über Forschungsarbeiten

Presented by the Engineering Standards Committee.

Copy of "British Standard Specification for Structural Steel for Bridges and General Building Construction."

Presented by the Government Printing Office, Washington.

(1) Copy of Technologic Papers of the Bureau of Standards: "Tests on Reinforced Concrete Beams." By Richard L. Humphrey and H. Losse.
(2) Copy of paper, "Portland Cement Mortars and their Constituent Materials." By Richard L. Humphrey and W. Jordan, jun.

Presented by the Association of American Portland Cement Manufacturers.

Ten pamphlets as follows :—
(1) *The Concrete Review*. Vol. IV., No. 6.
(2) "Concrete Surface Finish." By A. D. F. Hamlin.
(3) "Reinforced Concrete Chimneys." By Sanford E. Thompson, M.Am.Soc.C.E.
(4) "The Use of Cement in Sewer Pipe and Drain Tile Construction."
(5) "Concrete Silos." By C. W. Gayford and P. H. Wilson, M.Am.Soc.C.E.
(6) "Cement Stucco." By J. T. Simpson, C.E.
(7) "Concrete Tanks." By J. T. Simpson, C.E.
(8) "Concrete in the Counting." By J. T. Simpson, C.E.
(9) "Concrete School Houses," etc. By J. T. Simpson, C.E.
(10) "Concrete Highways."

Presented by Mr. Hubert C. Sands.

Copies of the Proceedings of the Surveyors' Institution, from the year 1902 to the year 1911 (4 bound volumes).

Presented by the Permanent International Association of Road Congresses.

Four copies of the Bulletin.

Presented by the Permanent International Association of Navigation Congresses.

Six pamphlets in reference to Congresses.

The following Journals are also sent gratuitously by the various Institutions and Publishers:—

Journal of the Royal Institute of British Architects
,, ,, Society of Architects.
,, ,, Surveyors' Institution.
,, ,, Institution of Technical Engineers.
,, ,, American Society of Civil Engineers.
,, ,, Architectural Association.
,, ,, Society of Engineers.
,, ,, Royal Society of Arts.
,, ,, Institution of Municipal Engineers.
,, ,, American Society of Mechanical Engineers.
,, ,, Institute of Chemistry of Great Britain and Ireland.
,, ,, Engineers' Society of Western Pennsylvania.

"The Architect and Engineer of California."
"The Architect."
"The Builder."
"Concrete-Cement Age."
"Concrete and Constructional Engineering."
"Engineering."
"Engineering News."

"Engineering Record."
"Ferro-Concrete."
"The Indented Bar Bulletin."
"Machinery."
"Page's Weekly."
"Southern Builder and Engineer."
"The Surveyor."
"Tonindustrie-Zeitung."

VISITS.

Works of David Kirkaldy and Son.

By the courtesy of Mr. William G. Kirkaldy, Assoc. M.Inst.C.E. (Member), members of the Concrete Institute visited the Testing and Experimenting Works of Messrs. David Kirkaldy and Son, of 99, Southwark Street, London, S.E., on Saturday, July 20, 1912. For convenience the party was limited to twenty in number.

London Works of Dorman, Long & Co., Ltd.

By the courtesy of Messrs. Dorman, Long & Co., Ltd., the members of the Concrete Institute visited the Works of this firm on Wednesday, July 24th, at Nine Elms Lane, London, S.W. The works of Messrs. Dorman, Long & Co. are for the manufacture of structural steelwork.

Premises of J. Sainsbury.

By the courtesy of Mr. A. Sykes, F.R.I.B.A., the members of the Concrete Institute visited a warehouse in course of construction for Mr. J. Sainsbury, situate at the corner of Bennett and Stamford Streets, close to Blackfriars Bridge, London, S.E., on Saturday, September 7, 1912.

This warehouse, which measures approximately 165 ft. long by 54 ft. wide, comprises six floors and roof. With the exception of the elevations to Bennett Street and Stamford Street the whole skeleton is constructed in reinforced concrete, lintels being provided in the outside walls to carry the brickwork, which has a thickness of 2 ft. 3 in. at the bottom. The

interior columns had to be kept down to as small a size as possible, and to carry the six floors heavily loaded a large percentage of steel was necessary, one of the lower columns requiring nearly 40 sq. in. In the ground floor three loading docks, 24 ft. by 20 ft. and 4 ft. 5 in. below ground-floor level, have been provided, each designed to carry a 10-ton axle load.

Each floor consists of a $4\frac{1}{2}$-in. slab carried on secondary beams 5 ft. to 6 ft. apart. This $4\frac{1}{2}$-in. floor is composed of $3\frac{1}{2}$ in. of 6 to 1 concrete and 1 in. of granite finish, laid simultaneously with the concrete. The secondary beams are 14 in. deep below slab and 7 in. wide, and have spans varying from 11 ft. to 15 ft. 5 in. The secondaries are carried on main beams 18 in. below slab, and 10 in. and 8 in. in width ; the span of the main beams varies from 12 ft. to 22 ft. 6 in.

Another interesting feature in this work is the retaining wall and vaults below the road in Bennett Street and Stamford Street. To carry the heavy road traffic in Bennett Street a superload of 10 cwts. per square foot was allowed on the roof of the vaults, and a corresponding lateral pressure on the retaining wall, and the lateral thrust on the building had to be carefully provided for.

The foundations are composed partly of independent footings to columns and partly of strip footings of various lengths and widths. Some trouble was experienced with the ground, and the foundations had to be carried lower down than at first intended, and in one case piles had to be driven to a depth of 12 ft. below foundation level.

The reinforcement throughout is "indented" steel bars, supplied by the Indented Bar and Concrete Engineering Company, Ltd., who are responsible for the engineering design of the reinforced concrete construction.

H.M. New Stationery Office and H.M. Office of Works Stores.

By the courtesy of Sir Henry Tanner, C.B., I.S.O., F.R.I.B.A., Principal Architect of H.M. Office of Works (Past President of the Concrete Institute), the

members of the Concrete Institute visited H.M. New Stationery Office and H.M. Office of Works Stores, in course of construction on a site abutting on Waterloo Road and Stamford Street, London, S.E. The entrance to the site is in Cornwall Road.

The new structure will be in two blocks, the larger, in Stamford Street, being the warehouse, and the smaller one, facing Waterloo Road, being the office portion.

A short street, Bazon Street (formerly Bond Street), separates the two portions, but they will be connected from the level of the first floor and upwards by arched beams of 28-ft. span, carrying a building 40 ft. wide and forming additional space for the offices.

The following give the general dimensions :—

Length of frontage to	Stamford Street	...	323 ft.
,, ,,	Cornwall Road	...	189 ft.
,, ,,	Doon Street ...	...	377 ft.
,, ,,	Waterloo Road	...	106 ft.
Average height of main fronts above footpath			77 ft.

Including ground floor and basement, there will be seven floors in the warehouse and eight floors in the office block, including sub-ground and basement.

The height, generally, from floor to floor will be 11 ft. in the office block and 10 ft. 6 in. in the warehouse.

The total floor area to be provided by the present contract is 380,000 ft. super, but the contemplated addition of a fifth floor and an extension over the remainder of the site will provide a further 100,000 superficial ft., or a total of roughly 11 acres for the complete scheme.

Internal areas, of which there will be two in the office block and three in the warehouse, will be provided to light the interior parts of the building. The windows of the warehouse will be provided with steel sashes.

The working of the warehouse will be carried on mainly by means of eight electric lifts for goods at the platform of the loading-yard in Doon Street. There are also two lifts for passengers, one for the offices and one for the warehouse.

For the office staff a dining-room, 55 ft. by 23 ft., will be provided on the top floor of the office building, together with kitchens, etc., specially fitted with steam and other cooking arrangements. In connection with this part a goods lift is provided for stores and for service at all floors from basement.

The drains inside the building will be of cast-iron pipes, laid under the basement floor.

A complete system of heating by hot water under forced circulation will be provided.

The reinforced concrete work is being carried out on the Hennebique system, the drawings for the reinforced concrete work being prepared by Messrs. L. G. Mouchel and Partners, Ltd. Messrs. Perry & Co., Ltd., of Bow, are the contractors. The following independent floor loads are allowed for :—

In warehouse, ground floor ...	3 cwt.	per sq. ft.
" other floors ...	$2\frac{1}{2}$ cwt.	"
In offices, all floors	100 lbs.	"
In roofs	65 lbs.	"

The floor slabs are $3\frac{1}{2}$ in. thick in warehouse and 3 in. thick in offices. External walls generally are 4 in. and 6 in. thick. The boiler chimney will be also of reinforced concrete, 4 ft. 3 in. sq. inside, 110 ft. in height, with sides 7 in. thick at bottom and 5 in. thick at top. It will be lined throughout with firebrick, set 3 in. clear of sides, and built in sections, supported by corbelling. All columns have octagonal bases designed to distribute a pressure not exceeding 3 tons per square foot on the foundation.

The front of office block facing Waterloo Road will be of Portland stone, carried by the reinforced concrete columns and beams, mainly at level of subground floor. This, together with all joinery, plumbing, and other finishing work, will be carried out under a separate contract.

Works of Drew-Bear, Perks & Co., Ltd.

By the courtesy of Messrs. Drew-Bear, Perks & Co., Ltd., the members of the Concrete Institute visited their Battersea Steel Works on Wednesday, October 9, 1912.

The entrance of the works is in Wellington Road, Battersea Bridge, London, S.W.

The following is a general description of the Steel Works :—

These works are specially laid out for the manufacture of steel stanchions, girders, beams, etc., for buildings, roof-work of all descriptions, and light bridge-work.

The works are driven throughout—with the exception of a few hydraulic machines—by electric power. The current, at 460 volts, is generated on the premises by means of :—

1. The prime mover : a gas-engine of 130 h.p., supplied by producer gas from a pressure-gas plant.
2. Two electric dynamos, which are belt-driven from the engine flywheels.

The hydraulic power is supplied by motor-driven pumps working to an accumulator, which delivers water to the machines at a pressure of 1,500 lbs. per square inch.

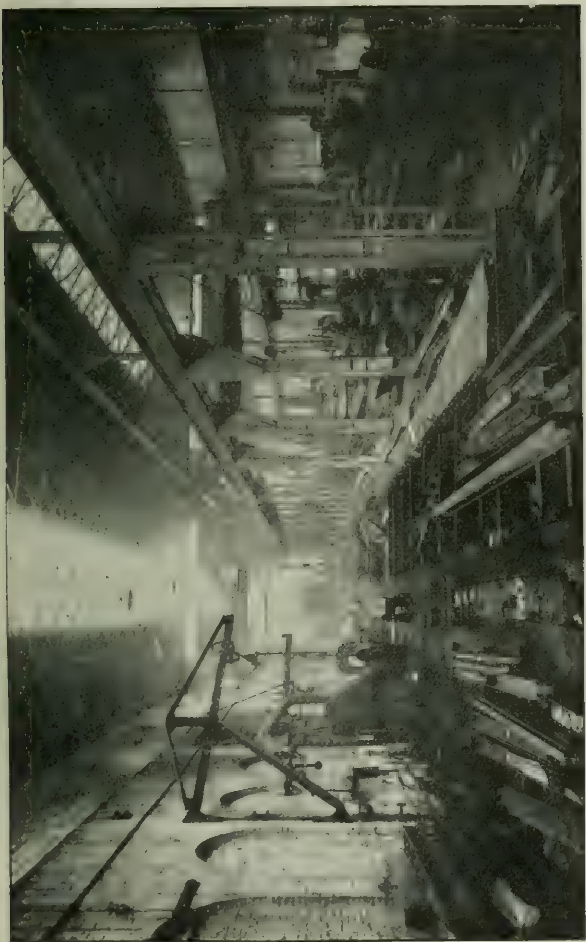
In the main workshop bay, which has a length of 250 ft. by 40 ft. span, the first machines we come to are two gangs each of 4-radial drilling-machines. Each gang is driven by an electric motor in a pit working a horizontal shaft in a trench under the machines. The machines have 6-ft. arms and turn a complete circle. High-speed steel-twist drills are used with spindle speeds varying from 170 to 270 revolutions per minute.

There is also a 6-ft. wall radial drill for odd work.

The next machine is an "Ender," also motor-driven. This machine has a self-feeding rotating head, furnished with two high-speed steel-cutter blades, and is used for planing ends of stanchions absolutely square and true with the central axis, and also for turning ends of built girders and rolled beams to a neat finish.

Next is a vertical punching, shearing, and angle-cropping machine, gear-driven by a 7-h.p. motor, fixed on top of machine, extreme capacity, punching 1-in. holes through 1 in. thick, shearing $\frac{3}{4}$-in. plates, cropping angles up to 6 in. by 3 in. or 4 in. by 4 in.

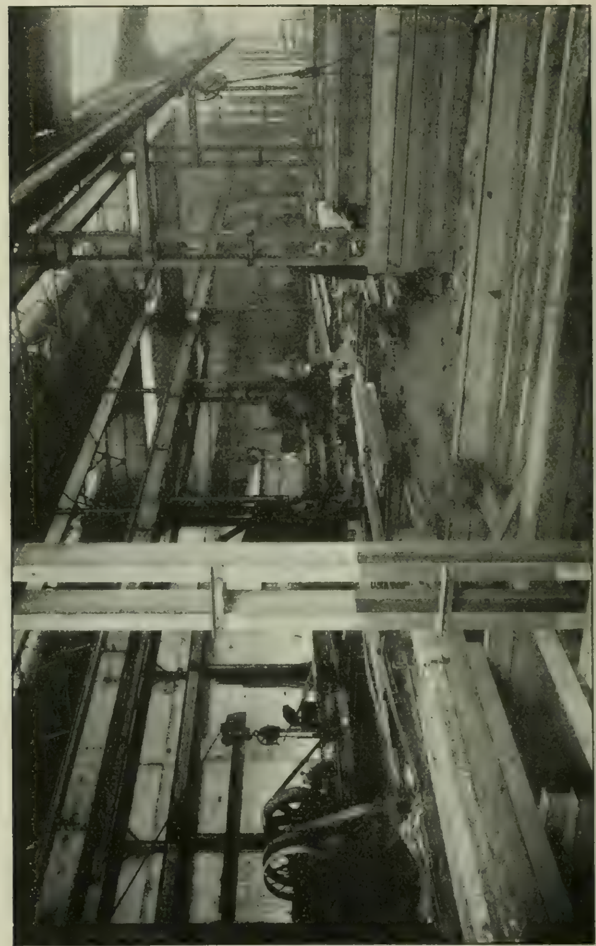
Next is a plate-edge planing machine, taking plates up to 30 ft. long.



Main Shop of Messrs. Drew-Bear, Perks & Co., Ltd.

Next is another vertical punching and shearing machine, without angle cropper, belt-driven by 6-h.p. motor in pit, capacity as previous.

Next we have a cold sawing machine, belt-driven by 6-h.p. motor. This machine is capable of cutting



Portion of Works of Messrs. Drew-Bear, Perks & Co., Ltd.

angles, tees, joists, and channels square or on bevel, the latter by means of a rotating head.

Turning round into the second workshop bay, 280 ft. long by 31 ft. wide, the first machine is an angle

and tee cropping machine, belt-driven by a 6-h.p. motor. This machine, by simple adjustments, can also crop angles and tees on the bevel.

The next machine is a powerful hydraulic machine for cutting joists up to 18 in. by 7 in. and channels up to 15 in. Two pressures may be used as required, single equivalent to 90 tons, double equivalent to 275 tons.

Next are two horizontal punching, bending, and straightening machines, gear-driven from motors.

The two hydraulic riveting machines are of the usual "Bear" type, and exert a pressure of 32 tons on the rivet when clenching.

There are five electric travelling cranes in the various bays, from $2\frac{1}{2}$ to 16 tons capacity.

In the smithy are the usual smiths' hearth and furnaces, lathe, saw, grinder, emery-wheels, and other small machines, also an hydraulic press for forging.

The template shop is of ample size and well lighted. Roof-work and all other complicated items, such as theatre balconies, are laid down full size on the floor and the necessary templates made from the lines.

Two illustrations of the works are here reproduced.

Works on Metropolitan Railway.

By the courtesy of Mr. W. Willox, M.Inst.C.E., Chief Engineer of the Metropolitan Railway, the members of the Concrete Institute visited the Metropolitan Railway's new offices at Baker Street, and the reinforced concrete bridge at King's Cross Station, in course of construction, on Saturday, October 12, 1912. The members assembled at the entrance of the Baker Street Station, London, W., at 3 p.m., and subsequently journeyed to King's Cross.

The following is a description of the works :—

Metropolitan Railway's New Offices.

The Metropolitan Railway Company is erecting a large block of offices adjoining the new station at Baker Street, to supersede the crowded offices at Westbourne Terrace and to concentrate in one building those at present scattered about various parts of their system.

The principal dimensions are as follows: The total length of the front elevation will be 140 ft., and the height, measured from the foundations to the roof, will be approximately 90 ft. The back portion of the structure will have two wings, measuring respectively 111 ft. in length by 38 ft. in width, and 100 ft. by 43 ft. for the smaller wing, the latter being connected to the booking-hall of the new station by a foot-bridge 82 ft. in span, 10 ft. wide, and with a height of 15 ft.

A retaining wall in reinforced concrete, and of a length of 152 ft., will run parallel to the front elevation. The total length of the retaining wall, including the returns, will be 212 ft., the height being 24 ft.

The walls of the building are to be entirely in reinforced concrete, of a thickness of 6 in., and for the principal elevation the wall is to be faced with brickwork and faience.

The building will comprise a lower basement, basement, booking-hall floor, ground floor, first, second, and third floors, and a flat roof. The superloads up to the first floor included are to be 150 lbs. per square foot, the second and third being 90 lbs. per square foot, and the roof 40 lbs. per square foot. The total superficial area of floors and roof in reinforced concrete will be approximately 65,000 sq. ft.

The building is to be carried on concrete stanchions over the new platforms, the lowest floor being level with the booking-hall of the new station; store and strong-rooms and the heating-chamber being at a lower level and alongside a set of rails, thus facilitating the handling of the coal for heating and the stores.

The ground floor, which is at street-level, accommodates the suites of the principal offices; and the board-room, which is planned between two committee-rooms, and with sliding doors, can be enlarged to hold the meetings of the company.

These rooms will be panelled in hard wood, with double partitions and windows to shut out any noise from the railway below.

The engineer's office is placed in the north wing, so as to get the necessary light for the drawing-office.

Automatic lifts are provided in the staircase halls, the south one descending to platform-level to facili-

tate the collection and dispatch of cash, tickets, etc., the north one connecting the accountant's and other departments with the strong-rooms in the basement. On the top floor are kitchens, dining-rooms, and caretaker's quarters.

The building will be heated throughout on the low-pressure hot-water system.

The whole of the work is under the control of Mr. W. Willox, M.Inst.C.E., Chief Engineer of Metropolitan Railway.

The architectural work has been designed by Mr. Willox's architectural assistant, Mr. C. W. Clark, A.R.I.B.A., P.A.S.I.; and Mr. O. G. C. Drury, A.M.I.C.E., is the resident engineer. The reinforced concrete work is on the Coignet system.

Reinforced Concrete Bridge at King's Cross Station.

The new bridge has recently been completed at King's Cross Station to connect Gray's Inn Road to Pentonville Road, through the site of the old booking-office. The whole of this work has been carried out under the superintendence of Mr. W. Willox, M.Inst. C.E., engineer of the Metropolitan Railway Company.

The bridge, which is built in reinforced concrete on the Coignet system, is claimed to be the largest road bridge of this description in London. The various dimensions of the works are as follows: There are two spans composed of straight beams, the bridge being slightly on the skew. The main span is 52 ft. and the smaller span 32 ft., giving a total length, taking into account the short end spans, of 130 ft. The width of the bridge, including the footpaths, is 60 ft.

One of the main features of this work is that it had to be constructed without interfering with the traffic of the railway below; and in order to support the wooden centering and moulds for the reinforced concrete work over the permanent ways, it was found advisable to utilise old steel trelliswork girders, which had previously been in use to support the floor of the booking-hall of the old station.

The roadway, which has been calculated for a uniformly distributed load of 2 cwt. per square foot,

and also for two moving point loads of 8 tons, situated at 6-ft. centres, has been designed in such a manner as to accommodate two lines of double-deck electric tramways of the usual London County Council type. Accommodation has been provided between the reinforced concrete beams for the special cast-iron yokes and ducks for the supporting of the rails and the transmission of the electric power.

The details of the reinforcement are in accordance with the Coignet system for the construction of straight beams. The main bars vary in diameter between $\frac{1}{2}$ in. and $1\frac{1}{4}$ in., and are of mild steel with a round section. The tension and compression reinforcing bars are connected together by means of stirrups, also made with round bars of small diameter. These vertical stirrups are arranged in such a manner as to take up the shearing stresses, and also in order to form a mechanical connection between the main reinforcement of the beams. The slabs are composed of bars varying between $\frac{3}{8}$ in. and $\frac{5}{8}$ in. in diameter and arranged to form a meshwork.

The work has been carried out by Messrs. W. King and Son, contractors, of London, licensees of the Coignet system.

THE CONCRETE INSTITUTE

AN INSTITUTION FOR STRUCTURAL ENGINEERS, ARCHITECTS, ETC.

(*FOUNDED* 1908. *INCORPORATED* 1909)

TRANSACTIONS

AND

NOTES

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The objects of the Institute are :—

(a) To advance the knowledge of concrete and reinforced concrete, and other materials employed in structural engineering, and to direct attention to the uses to which these materials can be best applied.

(b) To afford the means of communication between persons engaged in the design, supervision and execution of structural engineering works (excluding all questions connected with wages and trade regulation).

(c) To arrange periodical meetings for the purpose of discussing practical and scientific questions bearing upon the application and use of concrete and reinforced concrete and other materials employed in structural engineering.

The Institute is not responsible for the views of individual authors as expressed in Papers, Letters or Notes, but only for such observations as are formally issued on behalf of the Council.

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Major R. Napier Harvey, R.E.
Mr. William F. King.
Mr. R. H. Harry Stanger, Assoc.M.Inst.C.E

Mr. A. Alban H. Scott, M.S.A., *Hon. Secretary.*

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RECENT PUBLICATIONS PRESENTED BY THE AUTHORS AND PUBLISHERS.

Presented by the Author, Mr. H. St. G. Robinson.

Pamphlet entitled "Experiments on Adhesion of Old and New Concrete."

Presented by the Author, Professor Ira H. Woolson.

6 pamphlets :—

(1) Report of Tests upon Sand-Lime Brick.

(2) Two pamphlets entitled "Report of a Fire, Load, and Water Test."

(3) Two pamphlets entitled "Report of a Fire and Water Test."

(4) One pamphlet on Investigation of the Thermal Conductivity of Concrete, etc.

Presented by the Author, Mr. H. J. Harding.

One pamphlet entitled "Weight v. Measure."

Presented by the Publishers, Messrs. Constable & Co.

"Reinforced Concrete Bridges," by Mr. Frederick Rings.

Presented by the National Association of Cement Users.

"Final Report on Measuring Concrete."

Presented by the Association Internationale Permanente des Congres de Navigation.

"Rivers, Canals, and Ports: Bibliographic Notes."

Presented by the Deutschen Beton-Vereins.

Bericht über die XIV Haupt-Versammlung am 13, 14, and 15 Februar, 1911.

The following Journals are also sent gratuitously by the various Institutions and Publishers:—

"The Architect."
"The Architect and Engineer of California."
"The Builder."
"Concrete and Constructional Engineering."
"Concrete-Cement Age."
"Engineering."
"Engineering News."
"Engineering Record."
"Ferro-Concrete."
"Gas Engineers' Magazine and Gas Industries."
"The Indented Bar Bulletin."
"Machinery."
"Page's Weekly."
"Southern Builder and Engineer."
"The Surveyor."
"Tonindustrie-Zeitung."

Proceedings and Journals of the following Societies:—

City and Guilds of London Institute.
Engineering Society, University College, Cork.
Institute of Metals.
Institution of Mechanical Engineers.
,, ,, Municipal and County Engineers.
,, ,, Municipal Engineers.
Permanent International Association of Road Congresses.
Royal Institute of British Architects.
Society of Architects.
Society of Engineers.
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THE CONCRETE INSTITUTE

TWENTIETH ORDINARY GENERAL MEETING

THURSDAY, NOVEMBER 9, 1911

THE TWENTIETH ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held in the Lecture Hall at Denison House, 296, Vauxhall Bridge Road, Westminster, S.W., on Thursday, November 9, 1911, at 8 p.m.,

SIR HENRY TANNER, C.B., I.S.O., F.R.I.B.A., F.S.I., etc., the President, in the Chair.

THE CHAIRMAN (Sir HENRY TANNER) :—There are several candidates for election. The Secretary will read their names.

THE SECRETARY (Mr. H. KEMPTON DYSON) read the following list of names, all of whom were declared duly elected :—

MR. ARTHUR WM. BUNGARD, M.R.San.Inst., M.R.Soc.Arts, Licentiate R.I.B.A., Clerk of Works, H.M. Office of Works, London, S.E.

MR. WILLIAM HENRY WALKER, Architect and Surveyor, Birmingham.

MR. JOSEPH S. MCAVEN, Civil Engineer, Auckland.

MR. W. T. OLDRIEVE, F.R.I.B.A., F.S.I., F.S.A.(Scot.), Principal Architect, H.M. Office of Works, Scotland.

MR. B. O. REYNOLDS, Instructor of Civil Engineering, College of Engineering, Madras.

MR. S. G. ROBINSON, M.I.Mech.E., London.

MR. J. OSBORNE SMITH, F.R.I.B.A., F.R.San.I., London.

MR. RICHARD S. THOMPSON, Assistant Engineer, Otago Harbour Board, New Zealand.

MR. K. YOSHIDA, Engineer on the Imperial Japanese Railways.

MR. WILLIAM BELL, Chief Assistant to Messrs. D. & C. Stevenson, Civil Engineers, of Edinburgh.

MR. HENRY THOMAS BROMLEY, A.R.I.B.A., M.Inc.Assoc. of District Surveyors, District Surveyor for Wandsworth (East).

MR. E. PATEY CAMP, Clerk of Works, M. Junior Inst. of Engineers, London.

MR. PANDIT HIRA LAL, Assistant Engineer, Bilimora Railways, India.

MR. L. H. PACKER, Engineer, Gravesend.

MR. HAROLD F. PENTY, Architect and Constructional Specialist, London.

It was also announced that the Council had admitted MR. WALTER PAGE COOKE, of London, E.C., as a Student.

THE CHAIRMAN (Sir HENRY TANNER) then delivered his Presidential Address as follows :—

GENTLEMEN,—This Institute has now been in existence some three and a half years, and as this is the first Presidential Address that has been presented, it seems to be a fitting opportunity for taking stock of the work it has done during that period, and in so doing I may touch upon matters to which I have referred on other occasions. As some of you are aware, it came into being at a luncheon given by Mr. Edwin O. Sachs at the Ritz Hotel, in July, 1908, and the necessary regulations which had been prepared by Mr. Sachs were agreed to and Lord Plymouth was elected first President. Mr. Sachs is to be congratulated in so effectively organising a new Society. Under the regulations referred to the Council felt that they had very little power over the proceedings of the Institute, that power really resting with the Executive. This feeling became so strong that eventually the reconstruction of the Institute on similar lines to those of other Institutions of a like character came about, and these have worked satisfactorily, but are still open to improvement. However, at the time of the change the number of members was 881, which must be

considered as quite good, and is now about 875, while during the eighteen months ending last June the net gain had been 21. Of course, in the case of a new Society the numbers joining would naturally be large at the commencement, but still, I should look for a larger net accession than 16 in the third year; but we now seem to be slightly on the down grade, as the accessions have been rather less than the losses, owing to deaths, resignations, and removals, some names having had to be struck off the rolls from failure to remit their subscriptions.

The membership is distributed approximately as follows: 350 in London, 260 in the country, and 260 abroad; while the professions, etc., are represented by 582 engineers, 91 architects and surveyors, 31 concrete specialists, 45 chemists and cement manufacturers, and 28 contractors.

Less interest appears to be taken in the papers read and discussions thereon than was formerly the case, while it becomes increasingly difficult to obtain papers which are at once suitable and of sufficient interest. It is desirable, therefore, that the causes which give rise to this state of things which has arisen should be inquired into and remedied. I am aware that this is not the only Institute which is forced to make similar admissions, but this is a young Institute and there should be abundant energy in it. We cannot afford to sit still and leave things to take any course, and which may be downward.

These matters have been discussed by your Council, which at its last meeting appointed a Committee to consider and report how the Institute could best be broadened in its scope and interest and in its usefulness to members.

Concrete and reinforced concrete form parts only of structures; frequently there is much steelwork and other materials involved, including heavy timbering, either permanent or in false work.

It is considered, therefore, that structural engineering, being so intimately connected with our special subject, might well be regarded as coming within our purview, and that papers on such matters should be read and discussed. This is particularly the case having regard to the large number of engineer

members. This can be done without in any way trenching on the prerogative of other societies, as there is no institute dealing particularly with such subjects. I hope that the results which this Committee may arrive at will be to the distinct advantage of the members.

The Committee is empowered to take energetic steps to foster the structural engineering side, and thus we see how in future we shall in effect be not only a Concrete Institute but an Institution of Structural Engineers as well. With the extended field as indicated above, in which practically all our members are interested, and the majority actively engaged therein, our work should be much more valuable and our membership influenced accordingly.

In this connection, I cannot but think that membership requires better classification, and could usefully be rearranged on the lines of several of the engineering societies, and the Committee might well consider the point. There might, for instance, be members, associate members, honorary members, associates, and students. In the future, also, it may be possible and advisable for us to hold an examination in advanced structural engineering, which shall in no way trench upon the examinations of other bodies, but be supplemental thereto. Such prospects of extended scope for the energies of members is encouraging.

Further, I think that much more use might be made of the Journal. Many members and others must be in possession of information which would be of the greatest value to their brethren, while short articles of approved quality and matter would, I believe, be welcomed by the Council. The Journal should be issued regularly at intervals not exceeding three months.

Next, I wish to draw attention to the small attendance at the meetings. We can hardly hope that gentlemen will come forward to read papers, to open discussion, etc., unless they can rely on an audience of a reasonable number of people, and, with one or two exceptions, at the meetings this year the audiences were certainly not of that character. I trust that members will endeavour to show more appreciation of the proceedings and help to improve them. The smallness of the attend-

ance cannot be due to the situation of the present meeting-room ; it is slightly out of the way, perhaps, but is very convenient of access, while it is the best that could be done, having regard to our income. We shall probably manage to pay our way this year, and perhaps maintain our deposit account at its present level, notwithstanding that we have incurred considerable expense in removing and furnishing the new offices, which are found suitable and ample for our needs. What the balance may be, however, depends to some extent upon the payment of subscriptions in arrear.

The Annual Dinner was a success. We obtained the numbers expected, and I was supported by the Presidents of the Institute of Civil Engineers, the Royal Sanitary Institute, the Surveyors' Institution ; also Sir Alexander R. Stenning, a past President of that body, Mr. Edwin T. Hall, Vice-President of the R.I.B.A., the Mayors of Hampstead and Holborn, both well-known architects, Mr. John Murray, the Crown Surveyor, the Chairman of a Sectional Committee of and the Secretary of the Engineering Standards Committee, Mr. A. White, Deputy Chairman of the Associated Cement Companies, and many others—recognition of our Institute which will be regarded with satisfaction. Apart from this, the attendances at the Summer Meeting were not altogether successful.

Unfortunately, our income is small, and does not enable us to do many things which we could wish to have done for the information of our members. I hope that this will be borne in mind, and the better classification to which I have referred may afford the means to some extent for removing this disability.

I am pleased to be able to say that the Institution of Civil Engineers has taken up the subject of reinforced concrete through the Committee which it appointed some time ago, and to which my name was added in June of last year ; a considerable sum of money has been devoted to experiments which are in process of being carried out, and I hope for much advantage from what I may regard as the co-operation of that Institute. There is no doubt that experiments are needed in this country with a view to obtaining a consistent and complete series based on

materials to be obtained here and mixed and tested under similar conditions. At the present time we have to rely on experiments in America, Germany, and France, with cement of varying character and local aggregate, and it would be of the greatest advantage if these could be repeated in some cases at intervals for some years, the improvements in strength being so great. Perhaps this want may be removed.

For some time past the Joint Committee appointed by the Royal Institute of British Architects, upon which we are represented, have had under consideration the revision of its first Report, and the revised edition was published several months ago in a much more handy form than before and at the small price of 1s. As Chairman of the Committee I desire to thank the members of the sub-committees, upon whom the work really fell, for their labours so freely given ; while it is satisfactory to think that this Report so far as it goes is accepted generally as the basis of local regulations for governing buildings of this character. These regulations require to be framed in such a way that they can be amended in order to keep pace with the acquisition of fuller and more complete knowledge, which will, no doubt, come in due time. The importance of being able to do this is shown by it having been necessary for the London County Council to obtain an Act of Parliament in order to make such alterations and additions to its Building Act to admit of reinforced concrete being used in an adequate way, and so not prevent the development of a method of construction which has been proceeding in America and on the Continent at a pace considerably in advance of this country, and at a saving of much money, while under suitable conditions it is a far better method of construction to adopt for safety, as in the case of countries liable to seismic disturbances.

However, with the approval by the Local Government Board of the London County Council bylaws, after submission to several societies, including ourselves, for observations, it may be expected that there will be a considerable extension in the use of reinforced concrete in London, as also in other parts of the country, other cities having also taken steps to

admit of such methods of construction being used, and it may be hoped that the list may be much extended beyond what it was when the Local Government Board quoted Newquay as being the only place the building regulations of which specifically admitted of the use of reinforced concrete. Suitable bylaws to this effect remain to be added to the model code.

The preparation of such Reports and the adoption of bylaws regulating the use of reinforced concrete must tend to standardisation in design, and this must prove all for good. We have fortunately been fairly free from any serious failures in reinforced concrete construction, but experiences in America and on the Continent show that there is need for watchfulness. Although most of the failures have been attributed to bad construction, and the ignorance or carelessness of contractors and their employees, cutting in design may have been a contributory cause.

It is interesting to note that the American Joint Committee on Concrete, which some time ago, like our own Joint Committee, issued an interim or first Report, has now under consideration a further Report brought up to date.

The Board of Education appointed a Committee to inquire into the question of economy in building, and as to whether buildings of a more temporary nature could not very well be brought into use. Reinforced concrete came in for its share of the discussion, but the estimates of cost varied largely, from 33 per cent. less to 10 per cent. more than for ordinary building. No difference of locality will account for these variations. There can be no question of the greater durability of structures of these materials with a minimum expense for maintenance, less cost for heating, concrete being a good non-conductor, while the reduced cube must make for economy. It seemed to me that witnesses having a more intimate knowledge of the cost of such buildings might have been called, while it should be possible to standardise such buildings, and so effect considerable economies. A loan period of thirty years was referred to, while the usual loan period for schools of ordinary construction was stated to be fifty years. It is impossible to understand the difference in treatment. It is very little good encouraging specific

proposals for the use of novel materials or methods for public elementary schools when such differences of treatment prevail, and in effect penalising any new system of building, while local bylaws make no special provision proper to the use of reinforced concrete. In order, however, to remove this last difficulty, it was suggested in the report that legislation should be promoted to exempt school buildings the plans of which had been approved by the Board of Education from the operation of local building bylaws. It also recommended that the Building Regulations of the Board of Education should be revised with the same object of removing obstruction.

The Council inaugurated a series of lectures of an elementary character, given by Mr. R. W. Vawdrey, during the spring, which were fairly well attended, but we can scarcely hope to effect much good in competition with the courses given at the London County Council Schools and under the auspices of the London and other Universities, which have the advantage of testing apparatus, &c., and are generally better equipped. This is a matter worthy of the consideration of the Council.

The Standing Committees of the Institute have done good service; the new notation appears likely to be adopted generally in English-speaking countries, and its adoption is now being considered in America with, I understand, reasonable hopes of success. This, I think, must be regarded as very satisfactory. We have already intimated that we shall be happy to co-operate with the American Joint Committee in endeavouring to arrive at some common notation for English-speaking countries, the basis being that it shall be mnemonic, the symbols coinciding with the initials of the chief words in the terminology of the subject. In America there are some slight differences from our terminology for the same parts of construction. We think in these instances it should be possible to come to some agreement with material benefit to all concerned.

Our Committees have also submitted reports on the standardisation of drawings, and the testing of concrete, reinforced concrete, and materials employed therein, both of which are to be discussed at meetings

to be held early in the ensuing session, and I hope that the discussion will be full and as complete as possible.

Useful papers have been read before the Institute during the past sessions, and among those of last session that read by Mr. R. W. Vawdrey on "The Dissociation of Competitive Designs and Tenders" is one of much interest to many. The methods adopted for obtaining tenders are various, but it is seldom that tenders including design are asked for in any other branch of building than that of reinforced concrete. It is true that as a rule the general scheme is laid out by architects, and the reinforced-concrete designer has only to deal with the sizes of beams and columns, thicknesses of slabs, and their reinforcement, but even this involves a very large amount of work where repeated by a number of persons or firms; and it has to be remembered that quantities have to be prepared by the specialist, one reason being because the drawings are so incomplete that it would be impossible for any one else to prepare them. In the circumstances the quantities must be to some extent conjectural—a most objectionable state of things. Such quantities should, of course, be prepared from completed drawings and by an ordinary surveyor, as in the case of other processes of building, if competition is to be fair and on equal terms. The responsibility for their accuracy, however, lies between the specialist and the contractor, but the tendency is for any deficiency to be saved in some way, as, of course, in the case of keen competition there can be no margin to provide for such contingencies. With the architect's plans to work on there seems to be little opening for much variation when the R.I.B.A. rules have to be applied; nevertheless, there results very considerable divergence in the amount of the tenders submitted on such conditions, and this would seem to be due partly to the ordinary differences in builders' tenders and partly to the quantities of work to be done, of which there may be a dozen different sets. This plan avoids the selection of a specialist who is probably interested in some system and more or less indefinite patent, but it involves the employment of an expert to check the specialist, while the method affords open competition for the design and limited competition for the carrying out of the work. This seems to me to be

the wrong way about. From an architect's and from a surveyor's point of view the method is not satisfactory, and it prevents consultation and co-operation between the architect and specialist, which, to my mind, is essential to a proper arrangement and to the efficiency of the building and the best disposition of materials. Competition for design and construction must involve the utmost economy, which may perhaps be carried to the verge of safety ; otherwise there is very little prospect of the work being obtained, with the result that the labour involved is almost certainly thrown away. Economy in first cost appeals to most people, but there are other points to be considered, such as efficiency and the running of unnecessary risks, by which comparatively nothing is gained. The specialists, however, have the whole matter in their hands, and it is no use theorising while they submit their designs and tenders—or rather builders do so for them—on the mere chance of obtaining the work. It is almost impossible to make a satisfactory contract when there are no quantities attached thereto and few, if any, drawings, these being left to be approved afterwards, a course which no one would think for a moment of adopting in any other branch of building. The sooner the specialists agree among themselves as to how they are to overcome this grievance the better for them and every one else concerned.

Competition in reinforced concrete work has now proceeded to inordinate lengths, and it would seem that we have obtained the chief advantage to be derived from competition in design and that steps should be taken to put some limit to it. To effect this designers must be placed more in the position of consultants and not so closely associated with contracting firms as has hitherto been the case, and must remain so unless the two things can be dissociated ; and the expert, instead of checking the specialist, should co-operate, putting the latter on a higher plane. The disappearance of patent royalties and licences will no doubt facilitate the change.

Much is said about the architectural treatment of concrete and that that treatment should be appropriate to the material. This subject was dealt with by Professor Beresford Pite in a most interesting paper, and

we hope that the discussion may be continued in a full meeting later on. The subject is a difficult one, and formed one of the items to be discussed at the International Congress of Architects; but although there was some discussion, it was considered that the time was not ripe for any resolution to be moved. The great desire is to make the whole building of reininforced concrete, including the external walls, and develope some new method of architectural treatment. There are many opportunities for this, as in isolated structures where various methods of surface treatment may be adopted; but in town streets it is doubtful whether anything but stone or brick front elevations will satisfy building-owners or ground landlords. It seems equally logical to apply a stone or brick front to a reinforced concrete structure as to an ordinary steel framed and concrete one. However, perhaps the discussion which we hope for may produce novel proposals.

The question of "Fireproofing" was most effectively handled by Mr. Richard L. Humphrey at our meeting a fortnight ago and made most interesting by the various slides exhibited. This is a direction in which it might be possible to obtain much useful information if members would be good enough to forward to the Secretary any experiences that they may have knowledge of. There were two points that were well brought out—the superiority of a reinforced concrete screen wall over a brick one, from experiences at San Francisco, and the effectiveness of wired glass in preventing the spread of fire.

I now come to the future. The Institute has a strong Council and an energetic Secretary, who are anxious that the Institute should take its proper place in the scientific world, and the members look for information and general assistance. In the Press it has been stated that "the time has now arrived when the serious and long required technical and practical assistance to be expected of an Institution of this kind should be rendered to those who are entrusted either with the design or with the execution of works in concrete and reinforced concrete"; and that "if the Institute in its next few years does sound scientific and practical work on the broadest lines . . . its success

is assured, and that a very large amount of useful work is expected during the impending session, while papers are desired of greater technical interest than those presented during the past year," and a programme of papers is asked for.

To some extent, as I have shown, the Council has devoted itself to meeting the wants expressed above, and is, I think, fully alive to the necessity of obtaining good papers, but the great difficulty is to obtain the offer of them. Every one should therefore use his influence in this direction. After all, institutions of this nature are established for mutual information, and it is the business of all members to assist in this object. Everything cannot be left to the Council, its Committees, and the Secretary. I therefore ask for the active co-operation of all the members.

It may be thought that my remarks have a pessimistic tendency, but that is not intended, my desire being to urge all our members to take what part they can in the work of the Institute for the benefit of all. With the extension of our scope to include structural engineering in its broad aspect we shall have a wider outlook and a future of great usefulness, with a possibility of a considerable increase in membership. I therefore conclude with feelings of the most optimistic character. (Applause.)

MR. EDWIN O. SACHS, F.R.S.Ed. (Vice-President):—Gentlemen, I have been asked to propose a vote of thanks for Sir Henry Tanner's Presidential Address, the first address of its kind given in the Institution, and I think the members can congratulate themselves on having had such an interesting address, for it covers a vast field in a most interesting manner, and contains a very large amount of useful information and a number of very useful hints.

Sir Henry, at the close of his address, suggests that it might be regarded as being slightly pessimistic, but he emphasises the fact that he looks optimistically into the future.

I personally am somewhat of an optimist, and though this little child, the Concrete Institute, is now going through its children's diseases of the measles and scarlet fever, and so on, I am sure when it has recovered from these youthful ailments it will grow

up to be that strong and important and influential individual which many a man—to make the comparison — is to-day who has survived a somewhat delicate childhood.

Being an optimist, I like to dwell on Sir Henry Tanner's points which speak of the recent success of the Institute. Its greatest success during the last two years was, perhaps, its First Annual Dinner. That, at any rate, was really a great success for a young Institution. It was well managed, it went well, the speeches were interesting, and altogether it was a success ; and as an Institute we must give our very best thanks to Sir Henry Tanner for having personally arranged the dinner. If that may be taken as an example of what can be done by individual effort, I am sure that, if a great deal of individual effort is placed into the working of the Council, we shall have numerous successes of this description.

We also ought to congratulate ourselves that Sir Henry Tanner has been elected on the Institution of Civil Engineers' Reinforced Concrete Committee. It is an honour to this young Concrete Institute to have so able a representative there, and it is a very great step to think that the Institution of Civil Engineers, who in the earlier days of reinforced concrete—say, in 1908—ignored the subject, in this year—1911—not only has such a Committee at all, and the Concrete Institute's President serving on it, but that they are actually represented at our Dinner by their President. (Applause.)

We must also congratulate ourselves that this year we had representatives on the Joint Committee on Reinforced Concrete organised by the Royal Institute of British Architecture ; and here again we have the pleasure of having as our President this year the Chairman of that Reinforced Concrete Committee which has done such very good work.

Another point, I think, for congratulation was that we made a start with the elementary educational lectures of Mr. Vawdrey. They were most able lectures, and deserved far more support ; and if similar experiments are repeated, I am sure they will find favour.

The last point which I would like to mention in congratulatory vein is that the standard notation—

rather an obtuse subject—to which we devoted a considerable amount of time, is pleasing our American friends, and that we are at least half-way to some understanding as to a notation that is mutual to this side of the Atlantic and the other.

In the matter of membership and in certain other directions we have, perhaps, been marking time, but that does not matter very much as we were going rather fast in certain directions. It is very seldom that an Institute which is not two years old—as was the case when I ceased to actively conduct its affairs in 1909—should already be mentioned in an Act of Parliament as an authority to be referred to on questions of regulations. We had already in 1909 secured a standard which was quite that of many an older institution, and marking time is not necessarily an evil. There have been some administrative changes to make, and those administrative changes took time. Nothing better, however, could be said than what Sir Henry Tanner said in the latter part of his address, that now the administrative changes have been completed we should get to work, and do still more and better service for the science of concrete construction in the future. I hope that advice will be followed.

Personally, I would refrain from touching on the question of the inclusion of structural engineering among the subjects to be dealt with by the Institute. I have views on the matter, but they are not suitable for this meeting to-night, and the only thing I wish to emphasise is that, having devoted such considerable time to administrative changes, I hope that the coming year of the Institute will be mainly devoted to constructive and effective work, rather than to any further time-taking reorganisation of its constitution.

I think we have to congratulate ourselves on having Sir Henry Tanner as President. We have also to thank him for his very able Presidential Address, and no better recognition can be given than by according him a very hearty vote of thanks, and wishing him a most successful year of office. (Applause.)

Mr. ALEXANDER ROSS, M.Inst.C.E. (Vice-President) :—Mr. Chairman and Gentlemen, I rise with much pleasure to second the vote of thanks to our President, Sir Henry Tanner. Sir Henry has done

a great deal for this Institute: he has nursed it from the first and paid it every attention, never failed us, and is always willing to do something for our good and advancement.

I consider that the Institute has, as a matter of fact, made decided progress. It is comparatively new, and as the mover of this resolution has said, very few institutions at the same age stand so well before the public, and before the profession, as this one does. That being so, I think we must be very careful before we bring about any revolutionary changes. There is no doubt that changes may be right, and once it is decided that they are undoubtedly right, then changes ought to be made, but we ought to be very certain that we are on the right lines before we move.

Sir Henry necessarily talked to-night rather in a minor key. The membership has not gone up so rapidly as we all hoped it would. The meetings have not been so well attended as they might have been, but there is one great essential fact—the papers have all been very good. Those I heard I considered excellent.

One thing I might suggest. It has always struck me that possibly the endeavour to listen to an excellent paper, and discuss it, all in one night, is more than we ought to expect. I think probably it might be an improvement if we fixed the length of the meeting and carried on discussions as other societies do, night after night until the subject has been thoroughly exhausted. There are many advantages. It secures that the meeting may not become tedious, and every one knows exactly when it is to close, and then there is the other advantage, that there is a period of a week or more in which those who take an interest in the subject can look it up, and come next time prepared to give a thoroughly good account of themselves in discussing it.

Gentlemen, I am not going to detain you. As has been said, no discussion should be allowed on a Presidential Address. Nothing could be said on the address we have just listened to except in its favour and in its praise, and I have much pleasure in seconding the motion for a hearty vote of thanks to Sir Henry Tanner. (Applause.)

MR. SACHS :—I will put the motion to the meeting, and we will carry it with full acclamation.

The motion was put and carried amid loud cheers.

THE PRESIDENT (Sir HENRY TANNER) :—Gentlemen, I am very much obliged to you for the vote of thanks you have so cordially passed to me. I fear my remarks have been rather short, but perhaps they have had some pith in them. At all events, I was very anxious that the whole of the members of the Institute should see where we were, and understand really where we are wanting improvement. It seems to me almost the only way we can get to them. We can circulate this information scarcely in any other way, and I hope what I have said may produce better meetings, which will be more satisfactory to those people who come here and give us lectures.

I do not think I have anything to reply to in what has been said by Mr. Sachs or Mr. Ross, and therefore I will conclude.

I should say the date of the next Ordinary Meeting will be December 14th, when Mr. C. C. Workman will give a paper on "Some Recent Works in Reinforced Concrete."

We have provided refreshments in the offices upstairs, and we shall be glad if everybody will adjourn there.

The meeting then terminated.

TWENTY-FIRST ORDINARY GENERAL MEETING

Thursday, December 14, 1911

THE TWENTY-FIRST GENERAL MEETING of the CONCRETE INSTITUTE was held in the Lecture Hall at Denison House, 296, Vauxhall Bridge Road, London, S.W., on Thursday, December 14, 1911, at 8 p.m.

Sir HENRY TANNER, C.B., F.R.I.B.A., etc. (President), in the Chair.

The following were elected Members of the Institute :—

Mr. Arthur E. Evans, Designer in Reinforced Concrete, Westminster.

Mr. Philip Lewis Hanson, Contractor and Builder, Southall, Middlesex.

Mr. Septimus Charles Hanson, M. S.A. Assoc. Inst. San. Engineers, Architect and Structural Engineer, P.W. Dept., Lagos, Southern Nigeria.

Mr. William David Rees (Colonel, V.D.), M. Iron and Steel Institute, M. International Association for Testing Materials, Consulting Engineer and Contractor, Westminster, S.W.

Mr. Hubert Covell Sands, F.S.I., Architect and Surveyor, Lee, S.E.

THE CHAIRMAN :—I will now call on Mr. Workman, who represents Messrs. Edmond Coignet, Ltd., to read his paper.

Mr. G. C. WORKMAN, M.S.E., M.C.I., read his paper as follows :—

SOME RECENT WORKS IN REINFORCED CONCRETE.

SO much has already been said concerning the subject of reinforced concrete that I think it is possible to assume that the general principles and advantages of this comparatively new material are now well known.

The object of this paper is to describe a few of the numerous works recently executed in reinforced concrete, and to bring out some of the more interesting features of each particular case and to show how various difficulties have been overcome.

Owing to modern requirements, there is a growing tendency for the various branches of engineering to become specialised in order to obtain, by a continual study of each subject, the maximum amount of economy and efficiency.

It is for this reason that a certain number of engineers have become specialists in the designing of reinforced concrete, each one adopting the particular method of reinforcement which he thinks best suited for the purpose, and I may mention here that personally for the past ten years I have been identified exclusively with the "Coignet System," which was one of the first rational and scientific methods of reinforcing concrete.

As there are now a certain number of different ways of reinforcing concrete, I shall first give you a short description of the methods employed in the various works which I am about to describe.

Commencing with the beams, which are usually considered the most important part of a structure, round bars of mild steel are used, the diameter varying between $\frac{1}{2}$ in. and $1\frac{5}{8}$ in. The steel frameworks are designed in such a manner as to form independent units which can be easily made on the site and placed on the centering when required. In some cases the tension bars for the lower portion of the beams are all straight with a corresponding parallel bar in the upper compressed portion of the beam; a mechanical bond between the upper and lower bars is provided by means of stirrups made of round mild steel wire varying between $\frac{3}{16}$ in. and $\frac{1}{4}$ in. diameter. These stirrups have their ends bent

over the top bar, and they are fastened by means of annealed wire to the main bars so that their position cannot be changed during the process of concreting. The spacing of stirrups is, of course, varied in accordance with the shearing stresses.

Another method of preparing these steel frameworks consists in grouping together seven tension bars of comparatively small diameter; six of these bars are bent upwards at an angle of forty-five degrees and hooked over a longitudinal top bar $\frac{1}{2}$ in. diameter in such a manner as to form a kind of truss. Additional stirrups are also provided, as in the first method described, to counteract any extra shear.

This last arrangement has the advantage of being more economical than the first one because the section of steel in tension is made to decrease gradually towards the points of support where the bending moments are less, the extra steel being used to resist shear or diagonal tension.

In regard to shear I would point out that in the first method, comprising vertical stirrups and horizontal bars, the vertical shear is taken up by the main bars and the horizontal shear by the vertical stirrups, whereas in the last-mentioned alternative the vertical and horizontal shear, or, in other words, the diagonal tension, is counteracted by the bars bent at an angle of forty-five degrees.

The longitudinal top bar is, of course, necessary for the preparation of each unit. This bar is very useful to suspend the framework in the centering, and as it is situated in the upper portion of the beam it increases the resistance to compression. The upper end of the stirrups and shear members is secured by means of hooks to the top bar. This precaution is in accordance with the new rules of the Joint Committee of the Royal Institute of British Architects, which state that in every case care should be taken to bend or otherwise secure the ends of the rods to prevent them from slipping in the concrete.

The negative bending moments in beams are counteracted by joint bars of sufficient length.

In many of the buildings the steel frames of the pillars are made horizontally and placed in position in the casings when required. These frames are

composed of main bars bound together either by $\frac{3}{16}$ in. or $\frac{1}{4}$ in. wire, forming helicals or horizontal ties with a pitch of about 6 in. The object of these ties is not so much for strength as to keep

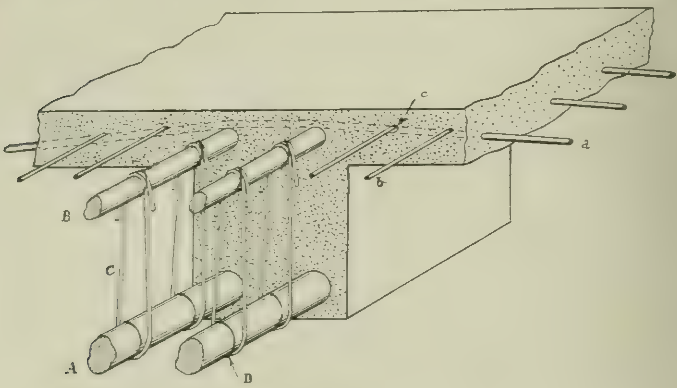

FIG. 1.

the vertical bars in their proper position during the concreting.

Concerning the reinforcement of rectangular floor slabs, this is provided by simply placing principal bars of about $\frac{1}{2}$ in. to $\frac{5}{8}$ in. diameter in the smaller spans and $\frac{1}{4}$ in. distributing rods at right angles to the others, so as to form a mesh, the bars of which are bent up gradually over the beams in order to resist contraflexure.

As previously mentioned, round bars have been used throughout because they have the advantage of being

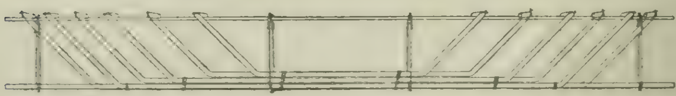

FIG. 2.

easily procurable in the open market, and because this section produces the minimum amount of contact between the various bars forming the units. It is obvious that flat surfaces of contact between bars

should as much as possible be avoided because rust is likely to develop in such places, and this defect may ultimately become a source of danger. Another reason for round bars being favoured is that they offer a

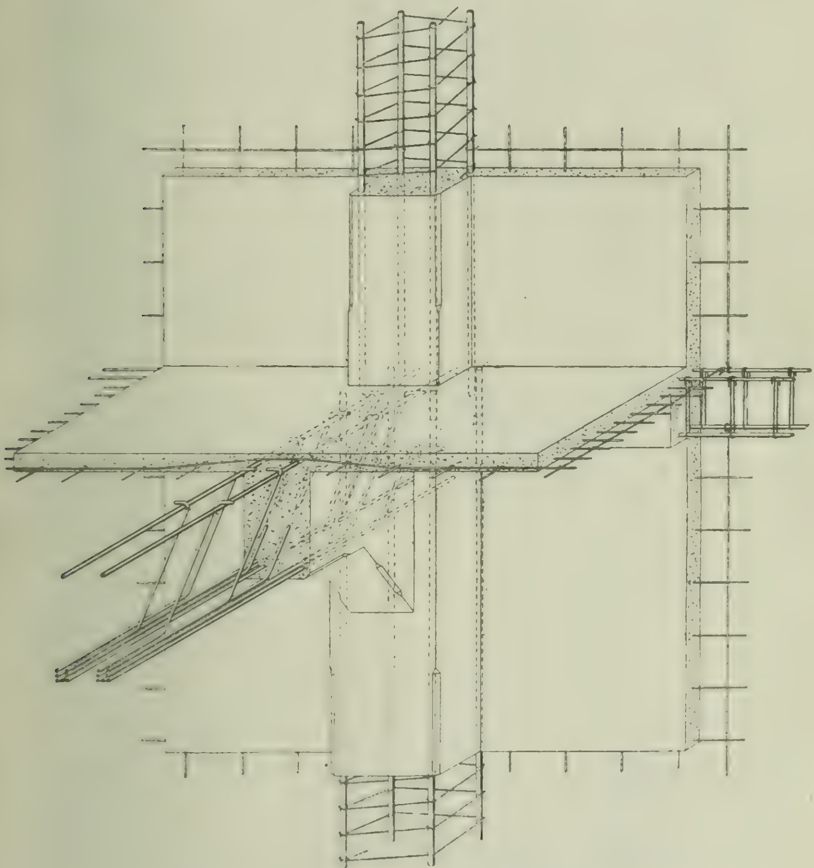

FIG. 3.

better surface of adhesion than any other available section.

Having briefly described the general principles of the reinforcement used in the buildings which I am

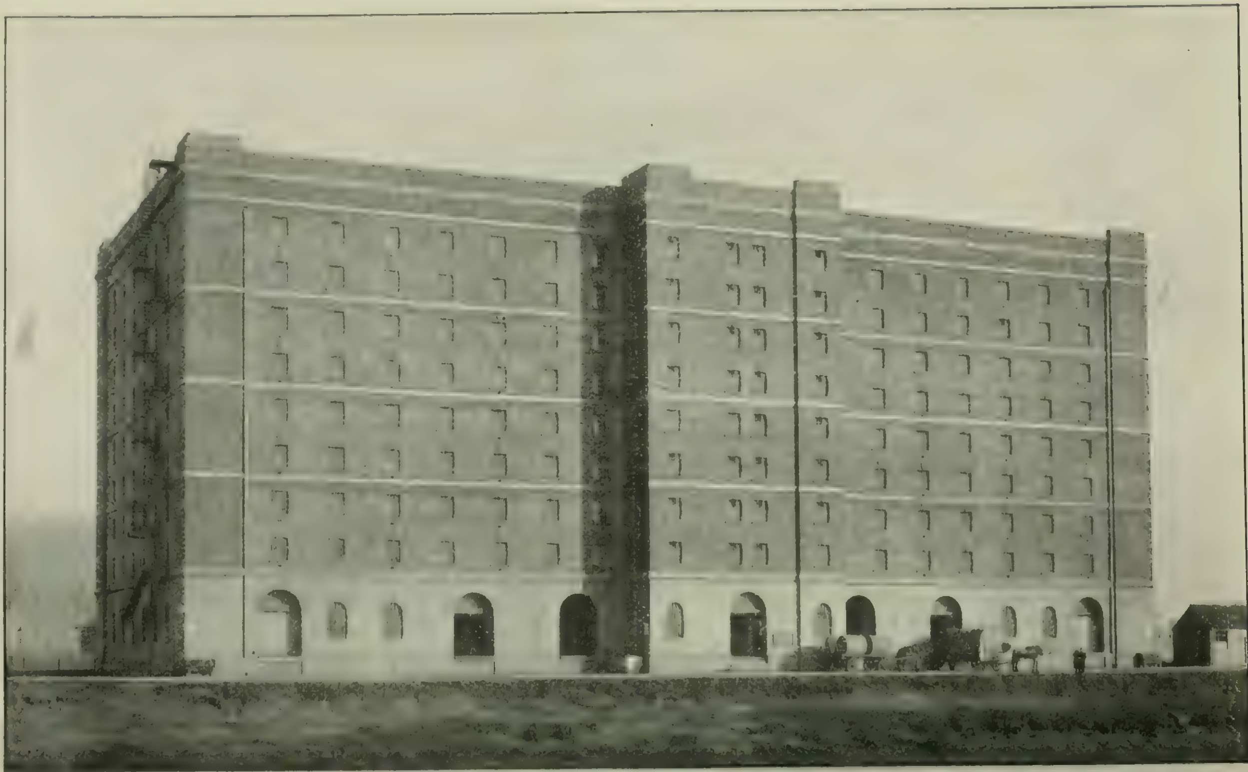

FIG. 4.—Bristol Tobacco Warehouse.

going to show you on the screen, it is my intention simply to deal with some of the interesting features in each case.

Before proceeding with illustrations of actual work I will first put before you a few diagrams showing the two methods of making steel frames for beams which I have already described.

Fig. 1 shows the stirrups gradually spaced along the beam in accordance with the shear. The section shows how the top bars are utilised to hold the units in position during the concreting by means of small pieces of wood placed under these bars and having their ends resting on the sides of the casing.

These top bars have also the advantage of keeping the bars of the slabs up at the junction of slabs and beams to take the tension due to negative bending moments, and it is important that the bars of the slabs should be held up as otherwise they are liable to be trodden upon by the men during the concreting, with the result that as the bars are not in their proper position to take up the tension, longitudinal cracks might appear over the beams, the concrete alone being left to resist the counterflexure.

Fig. 2 is a diagram of the alternative method of making steel frames or units for beams. The various bars forming the lower group are kept about $\frac{3}{16}$ in. to $\frac{1}{4}$ in. apart by means of wire passing between the bars and binding them together.

Beams made with these particular units are usually described as being of uniform strength owing to the fact that the section of steel in tension is calculated to correspond as exactly as possible to the requirements of the curve of bending moments.

Fig. 3 is a perspective drawing of a beam, slab, and pillar, also showing a lintel and walls.

One of the first large buildings with which I had to deal was the second tobacco warehouse, for the Bristol Docks (Figs. 4 to 7). This work was carried out under the Docks engineer, and the contractors were Messrs. W. Cowlin & Son, of Bristol.

The general dimensions of the structure are : 200 ft. in length by 102 ft. in width and about 96 ft. in height, and there are altogether nine floors calculated for a superload of $1\frac{1}{2}$ cwts. per square foot.

FIG. 5.—Interior of Bristol Tobacco Warehouse.

FIG. 6.—Bristol Piles on Site.

This building is identical in appearance to the first tobacco warehouse, but the inside is in reinforced concrete instead of being in steelwork with concrete floors.

Besides the advantages of fire resistance and economy which this building offers over the first one,

FIG. 7.—Driving Pile, Bristol.

the internal accommodation is larger on account of the walls being only about 14 in. in thickness throughout the height of the building, instead of the considerable thickness of brick walls required in the first building. These thin brick walls or panels were supported at each floor by lintels, and the building has

been divided in two by a partition in reinforced concrete 6 in. thick.

The various floors were arranged in such a manner as to minimise the risk of fire by cutting off any

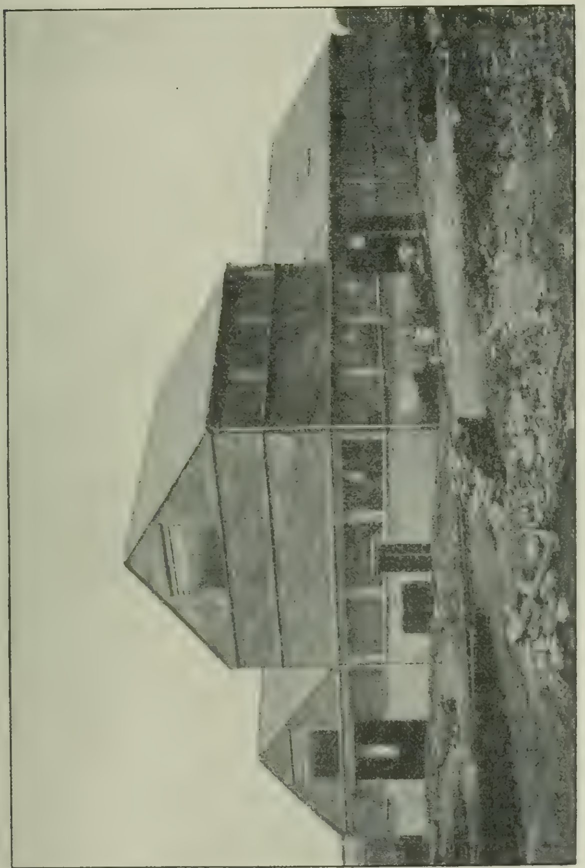

FIG. 8.—Building at Rainham.

particular floor from the others. The level of the floors is slightly raised at all lift openings and doors, so that it would be possible to flood any particular floor with a couple of inches of water if required.

This warehouse has been erected on reinforced concrete piles varying in length between 40 and 50 ft. Fig. 6 is a view of the site showing the piles maturing.

650 piles were required for the foundations.

The load coming on each of the internal pillars amounted to 300 tons, and it was necessary, in order to transmit this load on to the ground, to group six piles together, uniting the heads by means of a cap.

Each pile was calculated to stand a safe load of 56 tons, and the diameters of the piles varied between 14 in. and 15 in.

The piles were driven into the ground by means of a steam monkey weighing 2 tons. The particular pile shown in Fig. 7 took about three-quarters of an hour to drive to its final set at a depth of about 45 ft.

Fig. 8 is a photograph of one of several buildings erected at Rainham, Essex, for Messrs. J. C. & J. Field, Ltd., the architects being Messrs. Scott & Fraser, and the contractors Messrs. William King & Son, of London. The site is situated on the riverside and it is extremely marshy, so that the buildings had to be constructed on spread foundations or rafts in reinforced concrete.

It is noticeable that although this building contains very heavy machinery and tanks for the manufacture of soap, it has been possible to spread these loads on to the ground evenly at a rate of only about a quarter of a ton to half a ton per square foot.

Reinforced concrete buildings, being monolithic and lighter than brick or masonry work, are very well adapted to cases where unequal settlement is likely to occur, especially when such buildings are erected upon a reinforced concrete raft.

Fig. 9 shows a perspective drawing of extensive premises erected in the city for Messrs. J. Grossmith, Son & Co., perfumers. The architect was Mr. H. A. Saul and the contractors were Messrs. Peacock Bros., of Brixton, for the first portion of the building, and Messrs. Stuart's Granolithic Co., Ltd., of London, for the second portion, which is shown on the left-hand side of the illustration.

The building has altogether eight floors, the interior and roof being entirely in reinforced concrete. An

interesting feature of the building is that the heavy front and side lintels are supporting the whole of the brickwork above.

A considerable amount of difficulty was experienced in the design of the roof, owing to the fact that one of the slopes is much longer than the others, producing unequal thrusts.

All the steel units for the various beams and pillars were prepared at Brixton in the contractors' workshops, and carted on to the site ready to be placed in position.

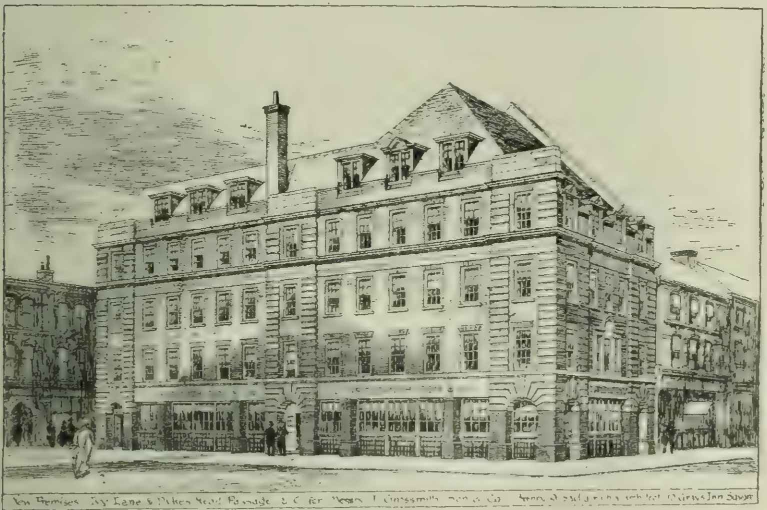

FIG. 9.

It was necessary to proceed in this manner owing to the lack of room on the actual site of the building.

Fig. 10 is a photograph of the flooring, during construction, for the hostel for women students at the Birmingham University.

The architects for the work were Messrs. Buckland & Farmer, of Birmingham, and the entire building was carried out by Messrs. Richard Fenwick, Ltd., contractors, also of Birmingham.

The total area of flooring was approximately 13,000 square feet.

These floors were tested with a load 50 per cent. in excess of the specified superload, and the deflection did not exceed a thousandth part of the span.

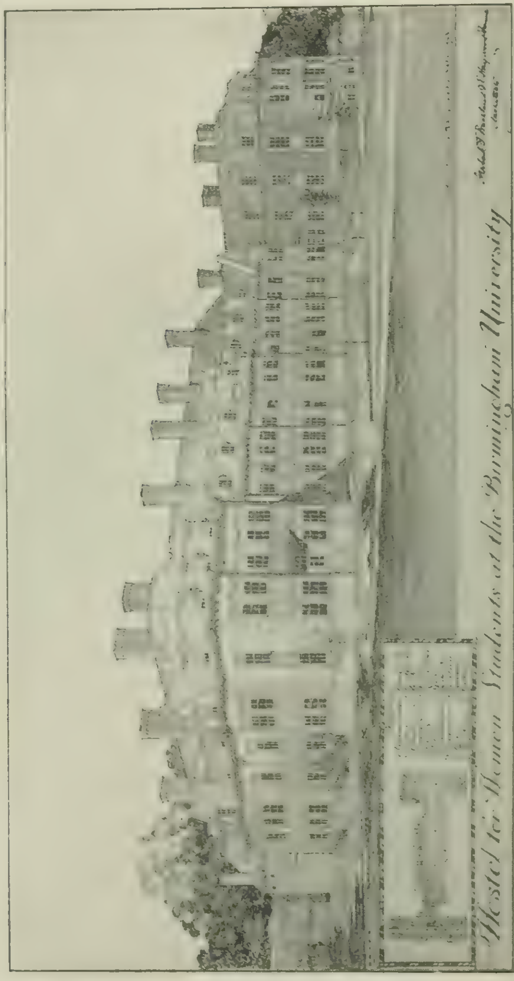

FIG. 10.

I would take the opportunity, while we have on the screen a photograph showing the process of concreting,

to mention that there seems to be a considerable difference of opinion between the various methods of stopping the concreting in floor slabs, in beams, and in pillars. Personally, I am of opinion that the best method of stopping the concrete of the floor slabs is to stop the work over the beams, also that the concreting of beams should be stopped over the points of support.

Concerning the pillars, the footings should be made first and the body of the pillar carried up to the level of the soffit of the beams, the remaining portion being concreted at the same time as the beams.

One of the most interesting buildings with which I have been associated is the new Western District Post Office, which was erected about two years ago under the supervision of the Office of Works, the contractors being Messrs. William King & Son, of London.

This building, which is situated between Cavendish Square and Wimpole Street, comprises a block of 200 ft. frontage and 160 ft. in depth, with basement, ground floor, first and second floors, and flat roof.

Fig. 11 is a view taken from the ground floor level, which is the main sorting-office.

Owing to the fact that only four large pillars were allowed in the centre of this floor space, the spans between these pillars and the outer walls varied between 45 ft. and 39 ft., so that the pillars, which are marked A, support loads of over 200 tons each.

One of the chief features of the building is that the ends of the principal beams carrying respectively the first floor, second floor, and roof are suspended bodily by means of strong steel stirrups to upper beams 6 ft. high, forming the internal walls surrounding the inner court above the various floor levels. By this means it was possible to obtain a maximum height for the windows, which was a condition stipulated by the Office of Works. This condition, however, brought about a question as to whether this method of suspension could be used without danger, the two beams having a span of 39 ft. and supporting the first floor with a superload of 1 cwt. per square foot, the upper supporting beam having a span of 45 ft. There was no evidence that this particular arrangement had ever been adopted before, at least for spans of such large dimension.

I am glad to say that the problem was solved in a satisfactory manner, with the result that the two suspended beams 39 ft. long each, and the beams across the inner court supporting the skylight, appear to have been made in one single span of about 118 ft.

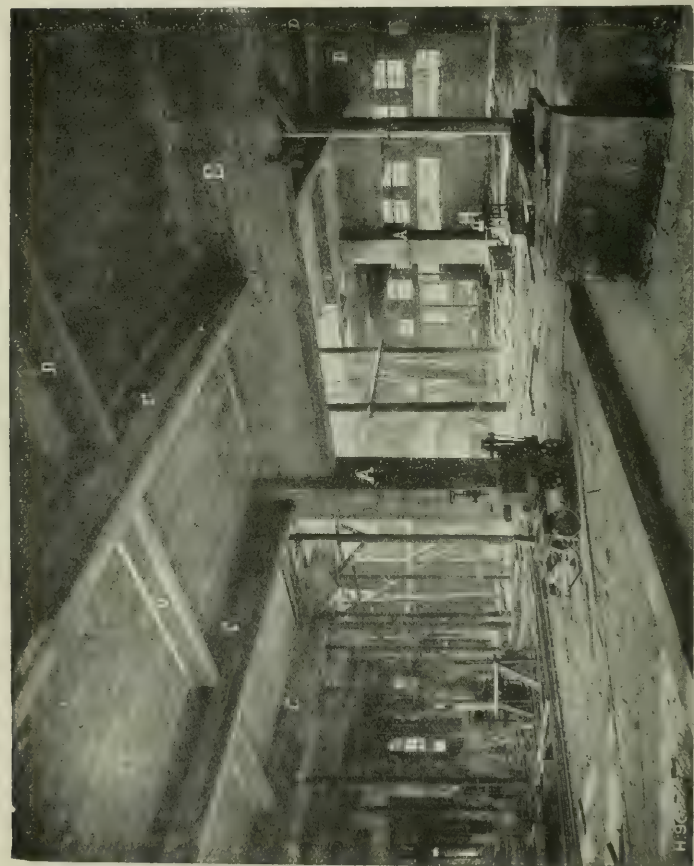

FIG. 11.—Interior of Ground Floor, Western District Post Office.

Another noticeable feature is found in the extensive beams over 12 ft. in height, which carry the other end of the suspended beams. These 12-ft. beams have a span of 45 ft., and it was necessary to provide in

the portion of these beams underneath the first floor a series of large windows situated below the neutral axis of the beam, which occurs approximately at the level of the first floor.

The pillars marked A are 34 in. by 34 in. The height between the ground floor and first floor is 18 ft. The two principal beams marked B are 14 in. by 60 in., with a span of 45 ft. They support two secondary beams marked C, the dimensions of which are 10 in. by 40 in. with a span of 37 ft., and these support other beams marked D. These beams are also suspended to the upper beam above the floor level, forming walls of the inner court, in the manner which I have already described, with the exception that these particular beams do not extend through the inner court.

Fig. 12 is a view of the first floor, showing the extensive area of flooring without any pillars.

The walls of the inner court marked E are the upper beams, 12 in. thick and 6 ft. high, with a span of 45 ft., which are supporting the suspended beams which I have already mentioned.

The two vertical projections shown on the beam E contain the steel stirrups by means of which the lower beams are suspended.

The beams F have scantlings of 14 in. by 48 in. and a span of 45 ft.

The two beams G, which apparently are resting on panels H, are in reality suspended to an upper beam similar to E.

Fig. 12 is a photograph taken just before testing. This operation was carried out by means of sand gradually spread over the surface.

Large areas of flooring were tested, the specification being one and a half times the superload, and the deflection not to be greater than $\frac{1}{600}$th of the span. The deflection recorded in the beams did not, however, exceed $\frac{1}{1500}$th to $\frac{1}{5000}$th of the span, and no permanent deflection was noticed.

I would take this opportunity to state that in my opinion it is essential to place underneath the beams which are to be tested a few strong emergency props not touching the soffit of the beam by about $\frac{1}{2}$ in. This has the effect of reassuring the men who are carrying on the loading operation, and it also has the

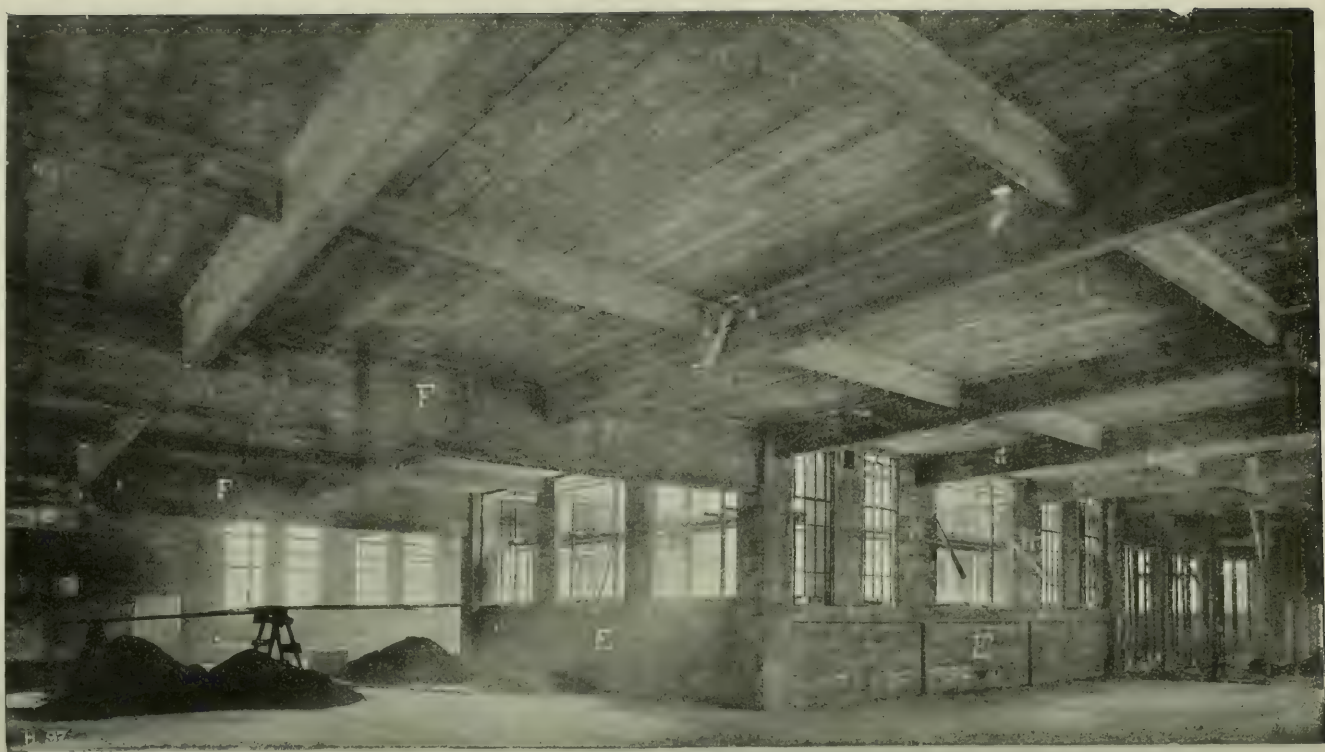

FIG. 12.—Interior of First Floor, Western District Post Office.

effect of preventing any sudden collapse which might be due to unforeseen circumstances.

Fig. 13 is the front elevation of the Western District Post Office in Portland stone, executed by Messrs. Galbraith & Son. All the other walls were made in reinforced concrete 5 in. thick. The London County Council By-laws which are shortly to be revised will, I hope, encourage architects to study the question

FIG. 13.—Western District Post Office.

of reinforced concrete applied to the front elevation of buildings.

Fig. 14 is a view of a large factory erected about eighteen months ago at Bailiffe Bridge, near Leeds, for Messrs. T. F. Firth & Sons, Ltd., carpet manufacturers. The architects were Messrs. Walsh & Nicholas, of Halifax, and the contractors Messrs. Henry Atkinson & Sons, Ltd., of Leeds.

The main building is four storeys high and 176 ft. long, with a width at one end of 70 ft. and at the other end of 111 ft., the building being in the shape of an "L." The total floor area is approximately 52,000 square feet.

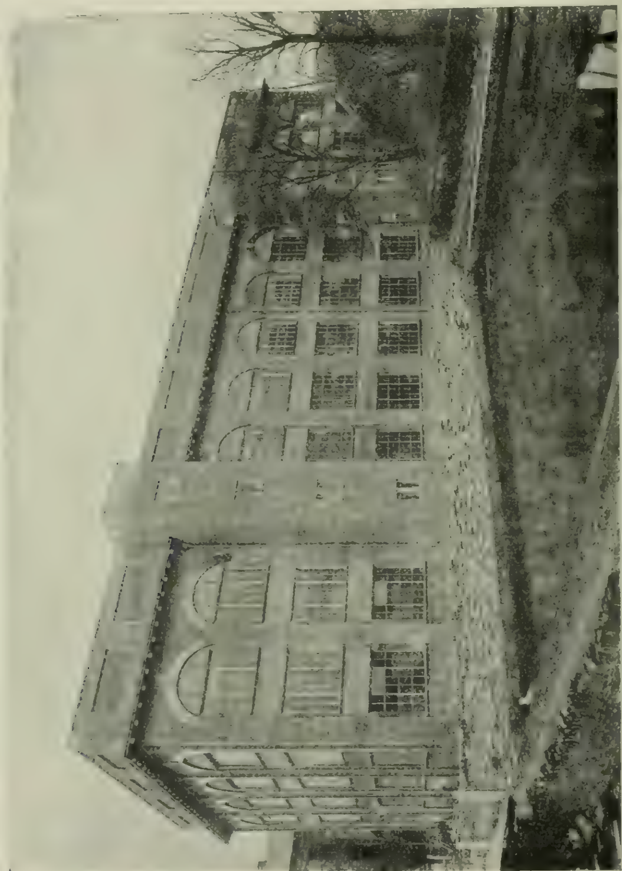

FIG. 14.—Factory at Bailiffe Bridge.

The factory is built on a very steep incline, and to overcome difficulties of levels on the site from the ground to first floor a retaining wall 16 ft. high was constructed in reinforced concrete.

The staircases throughout the building are also in this material.

The work being situated in the very midst of the York stone district, local prejudice prevented treating the external walls as a distinctly concrete building. A compromise was effected by facing the main reinforced concrete pillars and the lintels of the various floors with local self-dressed wall stones 5 in. on bed. The recessed wall spaces under the salt-glazed brick arches are finished with rough-cast.

I am informed that this large factory does not exceed in price per super-yard of floor area a similar factory which was built twelve years ago in the same neighbourhood with steel girders and stanchions, wooden floors and stone walls.

Fires are very frequent in this district, causing tremendous loss and inconvenience. The value of the carpets stored in this warehouse being very considerable, it was decided to adopt reinforced concrete for this building.

In this particular instance a very large saving was effected in the yearly premiums owing to the low rate which the Insurance Companies are prepared to grant to buildings in reinforced concrete.

Fig. 15 shows the interior of one of the floors with a central row of pillars, the span of the main beams being 35 ft. It will be noticed that the main beams have been arranged parallel to the windows in order to get the maximum amount of light for weaving purposes.

The floors are calculated for a superload of $2\frac{1}{2}$ cwt. per square foot with a factor of safety of four.

Fig. 16 is a view during the execution of the work showing the centering for the main beams. This affords a striking example of the advantage which there is in using unit reinforcement for the beams, because it enables the latter to be lifted bodily into the box moulds and suspended in the manner I have previously described, ready for concreting.

You will notice one of the units of a 35-ft. beam being placed in position by means of a crane.

The existing buildings and the new reinforced concrete workhouse are connected by means of two footbridges, having a span of 50 ft. each and a width of about 6 ft. (Fig. 17).

FIG. 15.—Interior of Factory at Bailiffe Bridge.

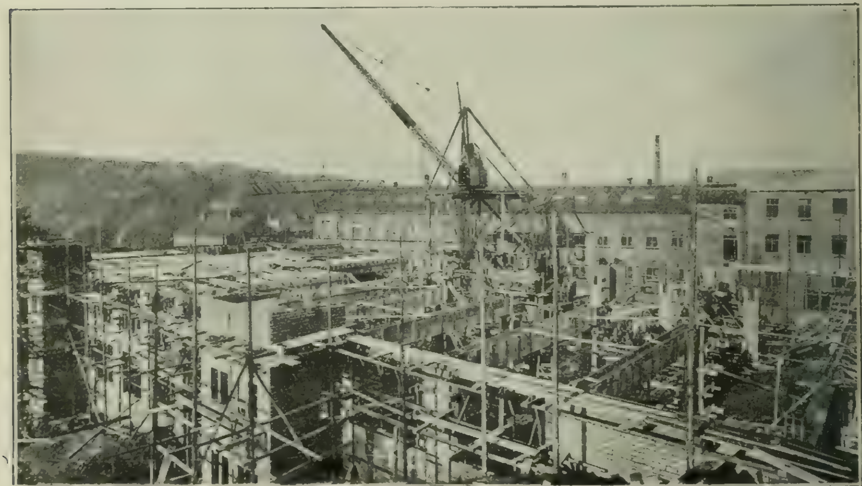

FIG. 16.—Warehouse, Bailiffe Bridge, in course of construction.

These foot-bridges are also made to support conveyors.

Although they have the appearance of an arch, they have in reality been calculated as straight beams in order to avoid any thrust on the walls.

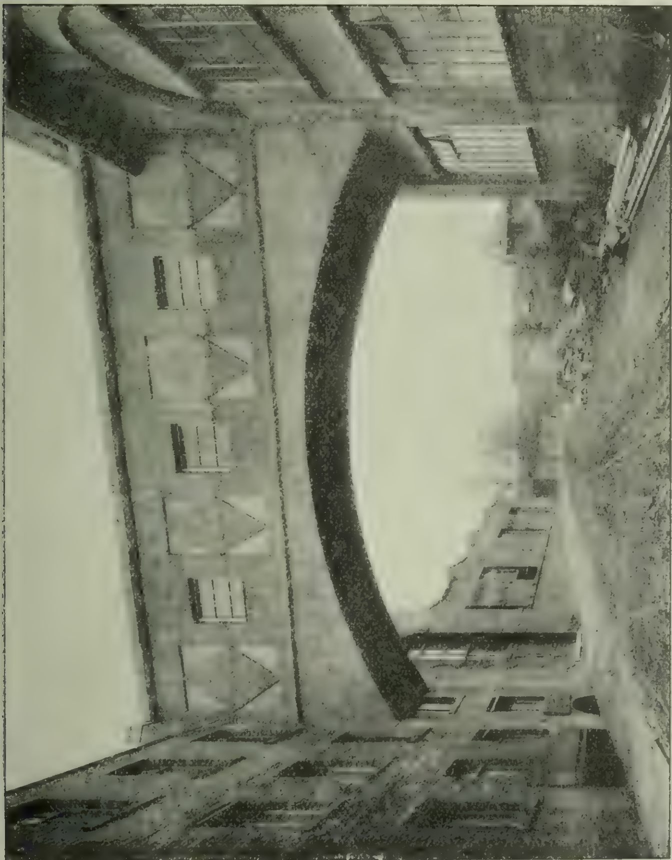

FIG. 17.—Overhead Bridge at Bailiffe Bridge.

A very large amount of reinforced concrete work has been carried out during the last two years in Jamaica.

Fig. 18 is a photograph of the new Government build-

FIG. 18.—Government Buildings, Jamaica.

ings erected at Kingston, Jamaica, for the Government. The architects were Messrs. Nicholson & Corlette, of London, and the contractors Messrs. William Cowlin & Son, of Bristol.

This large building, which is entirely in reinforced concrete, contains the General Post Office and the Treasury.

The dimensions of the Post Office building are 121 ft. by 132 ft., and the Treasury 187 ft. by 88 ft.

In preparing the design the architects had to consider the question of earthquakes, and consequently the foundations of these buildings have been constructed in such a manner as to offer the least possible obstruction to shocks or movements of the ground. The foundation is practically in the form of an immense raft composed of strong slabs and beams, the latter uniting the various footings of the pillars.

The superstructure is of the type usually adopted in hot climates with spacious verandahs and colonnades.

All the roofs are flat and covered with several inches of gravel.

Fig. 19 is a view of the back elevation of the building. The scantlings of the pillars vary between 24 in. and 18 in., and some of these are octagonal in shape.

The average span of the beams supporting the roof is 20 ft. and the average thickness of the slabs is 4 in.

The superload on first and second floors is 150 lbs. per square foot, and the roof was calculated for 84 lbs. per square foot.

The making of the steel frameworks and, in fact, all the labour was carried out by natives working under a few experienced supervisors. I am informed that most of the concreting was done by native women carrying the concrete in baskets.

Fig. 20 is a view of the new King's House at Kingston, Jamaica. This contract was carried out simultaneously with the one previously described, under the same architects and by the same contractors.

The foundations were also made by means of a raft, and, in fact, the same type of construction was adopted as for the public buildings.

FIG. 10.—Back Elevation of Government Buildings, Jamaica.

FIG. 20.—King's House, Jamaica.

A large swimming-bath was provided, and there are several remarkably fine dancing and reception halls.

This building is intended as a residence for the Governor of Jamaica. It is composed of a ground floor, principal floor, top floor, and flat terrace roof, the latter covered with several inches of gravel.

Needless to say, these buildings have been constructed not only to resist earthquake shocks but also to resist fire, and you will, no doubt, remember that a very severe conflagration followed the earthquake which happened in Jamaica many years ago. It is for this reason that practically all the buildings of any importance in Jamaica are at present being constructed in reinforced concrete.

Figs. 21 and 22 are the new Holloway Money Order Department, which is the latest of a series of large buildings for the extension of post-office facilities in London, under the instructions of H.M. Office of Works. The work was executed by Messrs. William King & Son, of London.

The entire construction, with the exception of the front wall elevation, is in reinforced concrete.

The building is in the shape of an "E." The total length of the front measures approximately 292 ft. and the depth of the main body about 50 ft.

The three wings measure respectively 88 ft. by 42 ft., 101 ft. by 42 ft., and 76 ft. by 42 ft.

The building is composed of a basement, five reinforced concrete floors, and a flat roof in the same material. There are also a large number of intermediate floors in the main body, which are used for cloak-rooms.

The total height of the structure from the ground level to the roof is approximately 85 ft., and all the stairs and balconies are in reinforced concrete.

Fig. 23 is a view of the completed elevation in brickwork and masonry, which was carried out by a separate contract by Messrs. Leslie & Co., Ltd.

Although the front elevation has been executed in masonry, the walls of the wings are in reinforced concrete of a thickness of 5 in. only.

The building is fitted with ventilating shafts and foul-air ducts, also constructed in reinforced concrete.

At the back of the building, and partly buried in the

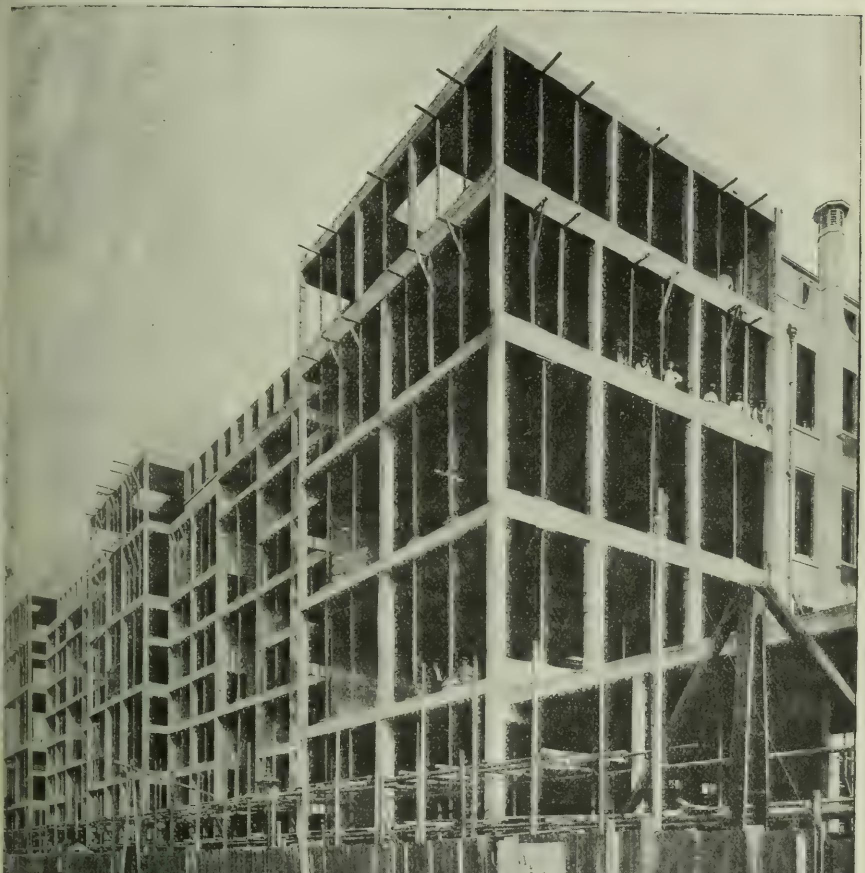

FIG. 21.—Reinforced Concrete Elevation of Holloway Money Order Department.

FIG. 22.—Back Elevation of Holloway Money Order Department.

ground, there is a large boiler-house, the dimensions of which are 47 ft. in length, 37 ft. in depth, and 26 ft. in height. It was necessary to construct heavy retaining walls for this purpose owing to the fact that the whole of the ground is composed of clay, and, as is well known, this kind of ground is rather treacherous on account of the fact that it has a tendency to become very soft in wet weather.

The underground passage in reinforced concrete

FIG. 23.—Necessary Elevation of Holloway Money Order Department.

provides a means of communication between the various wings of the building and the boiler-house.

A water reservoir, containing about 10,000 gallons, was also built, buried in the ground.

A remarkable feature of this work is the considerable rapidity with which it was executed. The concreting operations began at the end of December, 1909, and the entire building was practically finished at the end of July, 1910, so that, taking into account a month for preparing the excavations, concrete footings, etc.,

the reinforced concrete portion of this large building was erected in eight months, which, in my opinion, constitutes a record.

Fig. 24 is a photograph of the interior of one of the

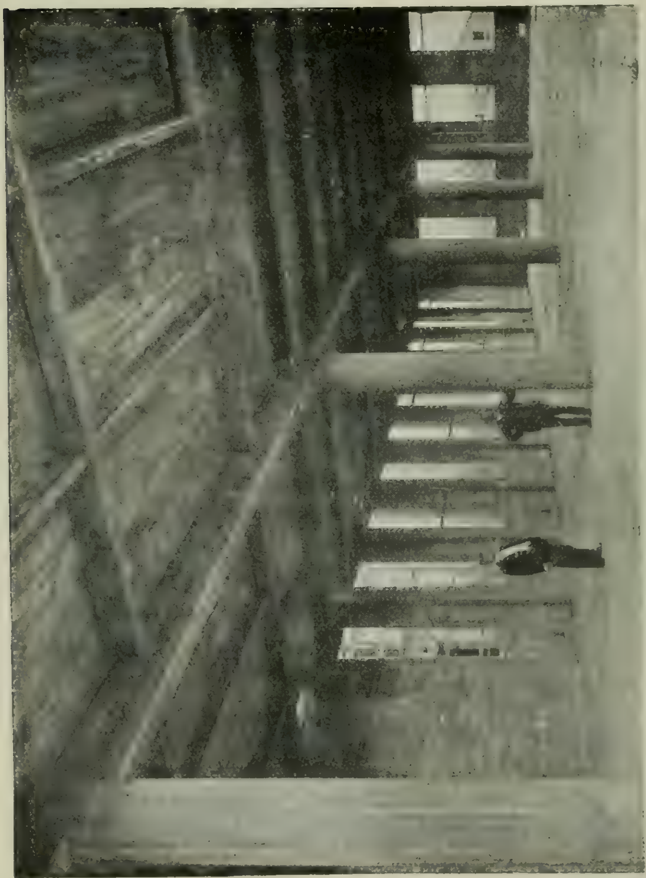

Fig. 24.—Interior of Holloway Money Order Department.

wings, showing the central row of circular pillars. The superload on the various floors was only $\frac{3}{4}$ cwt. per square foot, and the floors were tested by means of piling up bricks to a sufficient height to produce a superload of about $1\frac{1}{4}$ cwt. per square foot. There was

FIG. 25.—Footbridge at Erith.

FIG. 26.—Footbridge at Norwich.

no permanent deflection, and the results of the tests were considered satisfactory.

Whilst I am dealing with the question of superloads I would like to mention that it has been my experience that architects and engineers are inclined to specify superloads which are obviously far more considerable than what is really necessary. This is probably due to the fact that in many cases reinforced concrete is a novelty to them, and by specifying a comparatively high superload they hope to guard themselves against failure of the work. It is well established, however, that any failures which have occurred have been due either to the premature removal of props and centering, or, in a few isolated cases, to faulty design, so that in reality nothing is gained in security by specifying a higher superload than is required.

In the case of this building the Office of Works, who are thoroughly acquainted with the use of reinforced concrete, have not hesitated to specify a superload of $\frac{3}{4}$ cwt. per square foot, which is quite ample for their requirements, and which has the advantage, of course, of being economical.

All the works concerning which I have shown you illustrations and given you a description have been so far with respect to buildings. I will now show you some works of a different character.

Fig. 25 is a photograph of a foot-bridge erected on the Thames bank at Erith for the Erith Oil Works, Ltd. The construction was carried out by Messrs. Friday & Ling, of Erith, under the supervision and from the general design of Messrs. Scott & Fraser, architects, of London.

The total length of the work is approximately 150 ft. with a width of about 6 ft.

Fig. 26 is another illustration of a foot-bridge at Higham-Hellesdon, erected by Messrs. D. G. Somerville & Co., under the supervision of Mr. A. E. Collins, the City Engineer of Norwich.

The total length of the foot-bridge is approximately 340 ft. with a width of 7 ft. It was built on fifty piles 13 ft. long each.

Figs. 27 and 28 are views of a road-bridge erected at Mauld, near Inverness.

The work was carried out by Messrs. McLaughlin & Harvey, Ltd., contractors, of London and Belfast, under the supervision of Messrs. Scott & Fraser, archi-

FIG. 27.—Mauld Bridge.

tects, of London, who are responsible for the general design of the work.

The total length of the bridge is 180 ft. with a width

D 2

FIG. 28.—Pier at Mauld Bridge.

FIG. 29.- Bowstring Bridge at Bargoed.

of 12 ft. between parapets. Four of the spans measure 35 ft., and the remaining span measures 45 ft.

The river is liable to become very high and the current is very rapid at certain times of the year. It was found necessary to design the bridge in such a manner as to protect the piers against the shock of floating timber, and also to resist the shocks of the floating blocks of ice during the winter months.

The foundations of the piers were made by driving a certain number of reinforced concrete piles in the bed of the river, encasing these in a solid block of concrete.

Fig. 29 is one of two bridges erected for the Powell Duffryn Steam Coal Co., Ltd., under the supervision of their engineer, Mr. J. M. Greenhow, the contractors for the work being Messrs. Watt Bros., of Cardiff.

This bridge, which is of the bow-string type, is calculated to carry two lines of railway with locomotives weighing 50 tons and wagons 19 tons each.

The bridge is built on the skew, the dimensions being 56 ft. 9 in. in span with a width of 26 ft. 8 in. and a height of bow-string beam of 13 ft. 3 in.

The remarkable feature of this bridge is that it has been constructed underneath and on both sides of an existing steel bridge, which had become unsafe owing to corrosion produced by the fumes of sulphur and ammonia. The advantages of reinforced concrete in such cases are obvious. The reinforced concrete bridge was first allowed a sufficient time to harden and was then ready for service on the removal of the existing steel bridge, which operation was carried out in 48 hours. I had the opportunity of testing this bridge quite recently. The test was carried out by means of locomotives and loaded wagons, the maximum deflection under the bow-string beams being only about $\frac{1}{16}$ in. without any permanent set.

Fig. 30 is a view of an elevated tank, also for the same Mining Company, erected by Messrs. Watt Bros., of Cardiff.

The general dimensions of the tank are 100 ft. long, 32 ft. wide, and 5 ft. 3 in. high.

The remarkable feature of this tank is that although the inside was not rendered it is perfectly watertight. This is due to the fact that the aggregate was very carefully graded, and also on account of the height of the water being only 5 ft.

Fig. 31 is a photograph showing the underside of the large bunkers erected at Kinlochleven for the British

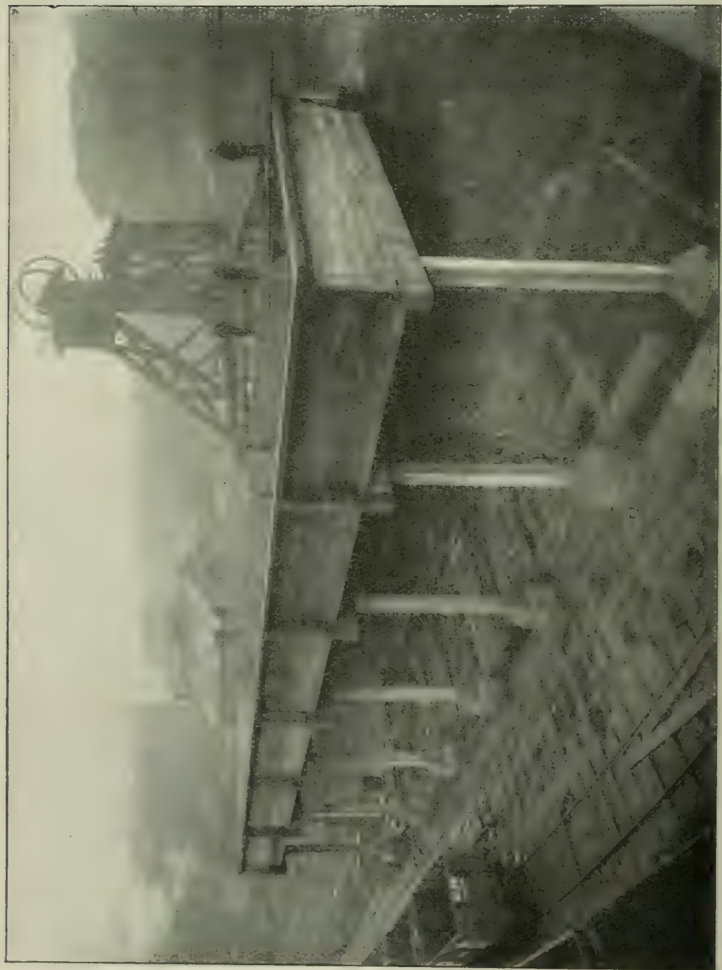

Fig. 30.—Elevated Tank at Bargoed.

Aluminium Co., Ltd. A very large amount of reinforced concrete work was erected for this Company from the designs and under the superintendence of

Mr. A. Alban H. Scott, M.S.A., the contractors being Messrs. R. McAlpine & Sons, of Glasgow and London.

The total capacity of this large bunker was over 80,000 cubic feet.

The main feature of this enormous work is the suspended hopper shown in the illustration, which has

Fig. 31.—Underside of Bunkers, Kinlochleven.

been calculated to carry a total load of about 2,000 tons in addition to its own dead load.

This bunker is divided up into a certain number of transverse compartments forming large suspension beams, carrying the horizontal beams and inclined panels of the hoppers. In this manner the entire space underneath the bunkers is free for conveyors and other machinery.

Fig. 32 is a view of the West Pier, Newhaven, which

FIG. 32.—Jetty at Newhaven.

has been underpinned by means of about 700 reinforced concrete piles. This work was carried out under the supervision of Mr. Charles Morgan, Engineer-in-Chief of the London, Brighton & South Coast Railway, the contractors being Messrs. W. Hill & Co., of London.

It was found necessary to replace the old wooden piles supporting the concrete work on account of the decayed condition of the wood.

FIG. 33.—Lifting Pile at Newhaven.

The reinforced concrete piles, or more accurately sheet piles, were 16 in. by 16 in. in section, and some of the longest piles measure 52 ft. over all. They were driven by means of a steam monkey weighing 2 tons.

Some of the piles were driven a considerable distance into the hard chalk, which is a proof of the strength of reinforced concrete piles.

When visiting the works I had the opportunity of

seeing one of these piles, weighing over 6 tons and measuring 52 ft. in length, being lifted at one end by means of a crane, the other end resting upon a truck. The deflection in the middle appeared to be only about ½ in. (Fig. 33).

I am informed that some of the piles for the Bristol Tobacco Warehouse, which I have previously described, were elevated in a similar manner, producing a deflection in the middle of over 1 in. without any apparent injury to the concrete.

The obvious conclusion is, of course, that reinforced concrete piles possess, and, in fact, reinforced concrete in general possesses, a very considerable amount of elasticity.

Fig. 34 is a view of a wharf recently constructed by Messrs. D. G. Somerville & Co. for Messrs. J. E. Butt & Sons, at Portslade.

The work is composed of piles and sheet piles connected by means of beams and supporting reinforced concrete panels held in position by means of tie beams and concrete anchor blocks.

The main piles are 12 in. by 12 in. with a length of 25 ft. These piles were driven 15 ft. centres, the intervening space being made up with sheet piles 22 ft. long, having a sectional area of 6 in. by 18 in.

The remarkable feature of this work is that the piles and sheet piles had to stand very heavy blows owing to an exceedingly hard stratum of ground through which they had to be driven.

There are a certain number of other works recently erected with which I have been connected, which I should have had great pleasure in describing to you. I find, however, that this would require more time than I have at my disposal.

I have endeavoured in the various examples of work which I have placed before you to illustrate all the various uses of reinforced concrete, namely, for floors, beams, pillars and walls, spread foundations, also foundations by means of piles, bridges, bunkers, water-tanks, and finally marine works.

I will now conclude by saying that the object of this paper has been to show how certain practical difficulties may be solved in reinforced concrete construction, and it is my hope that some of the works

FIG. 34.—Wharf at Portslade.

which I have put before you to-night will still further strengthen the confidence which English architects and engineers are showing in this comparatively new method of construction.

DISCUSSION.

Mr. F. E. WENTWORTH-SHEILDS, M.Inst.C.E.: —Mr. Chairman and gentlemen, I have very great pleasure in proposing a most hearty vote of thanks to Mr. Workman for his very interesting paper. In fact, I have a feeling of gratification that I am, perhaps, in some slight measure responsible for this paper, as I used my best endeavours to persuade Mr. Workman to give this Institute a paper in which he should describe the large number of works with which he has been connected in this country, and I am sure we are all very grateful to him for having shown us, by means of these slides and by his lucid description, the varied work which has been done by his firm. Mr. Workman represents in England a man who is the son of a pioneer, if not *the* pioneer, of reinforced concrete. Those members of this Institute who had the pleasure of being shown over certain works in Paris last year will remember that M. Coignet showed us a reinforced concrete roof that was constructed near Paris by his father, M. François Coignet, some fifty-eight years ago; and we recollect that he not only showed us this roof, but that he was good enough to have a hole cut into it so that we might see that the steel, which was put there more than half a century ago, was still in perfect condition. We were very much struck with the fact that although the science of reinforced concrete was then quite in its infancy, M. Coignet had seized the idea of the right disposal of steel in concrete, and had put his steel on the under side of his slab in order that it might take up the tensile stresses. In fact, that roof was a correctly designed reinforced concrete slab.

Coming to modern times, and dealing with the various structures which Mr. Workman has described to us this evening, there are one or two questions I should like to ask him. With reference to the piles for the Bristol tobacco warehouse, which I imagine, from their circular form, were helically reinforced, I should like to know whether he used a helmet filled with sawdust or any softening material, or whether he

drove the piles with a wooden dolly or without any sort of pad, allowing the ram to fall directly on to the pile. As a matter of fact, I have seen a pile that was not helically reinforced driven without a helmet quite successfully, but the pile was protected in a measure by being surrounded with very strong clamps or straps, which acted, as it were, as a temporary helical reinforcement to prevent the concrete bursting under the blow of the ram.

I should also like Mr. Workman to give us, if it is not asking too much, a little detail of the design of that large column he showed us in the post-office building, which, he said, had to support a load of two hundred tons. It was a very large column, and it would be rather interesting to know whether, for instance, there were four rods in it or six rods in it, and how the steel was placed, and whether there were transverse stirrups or connections between the main rods, and if so, how they were placed.

It would also be very interesting if he could give us some details of those suspended beams, which, I think, are perhaps rather a novelty—at all events, for a beam of that size. We should like to have some details of the suspension—how the links were attached to the main beam and to the beam below.

One more question I should like to ask Mr. Workman, and that is, after all his experience in buildings, what does he recommend for covering a reinforced concrete flat roof? That is a difficulty which many engineers have to struggle with. In France, I believe, the common plan is to cover the top of a flat roof with sand, or even with garden mould, but the English mind seems to shrink from growing geraniums on the top of a house, it prefers to have them down below. (Laughter.) I have only had personal experience of one flat reinforced concrete roof, and in that case the roof was covered with some kind of waterproof sheeting, and a layer of concrete was laid over that again, and the roof thus formed, being surrounded by low parapet walls, was used as a shallow water tank. It was found, however, that the water somehow or other got into the room below, therefore the water was withdrawn, after which the water got through worse than ever. (Renewed laughter.) That is to say, every time there was a

shower of rain, through it came. An effort was made to stop that by covering it over with some sort of felt, which was only partially successful. It would be very useful to know whether Mr. Workman has had any difficulty with his flat roofs, of which he appears to have constructed a good many, and what solution he has arrived at for this particular problem.

I should also like to call attention to a paragraph in the second page of his paper where he says, "In regard to shear I would point out that in the first method" (that is to say, in the method of using horizontal tension bars with vertical stirrups) "the vertical shear is taken up by the main bars and the horizontal shear by the vertical stirrups. That is a thing that I have often thought about. Mr. Workman says that the vertical shear is taken up by the main bars. Personally, I am still rather doubtful of that, although I have his authority on the matter, because, when one comes to think of it, the principal shear stresses, both vertical and horizontal, are at the neutral axis, and at that point there are no horizontal bars. Of course, the horizontal bars are at the lower edge of the beam, or in doubly reinforced beams they are at the lower edge and the upper edge; there are none at the neutral axis, where the shearing stresses are greatest. I would, therefore, feel inclined to ask Mr. Workman whether, bearing this in mind, he still maintains that the vertical shear is taken up by the main bars in cases where there is no inclined reinforcement.

I gather from this paper, and also from work which I have known Mr. Workman to carry out, that he is an advocate of the system of having a large number of small bars and bending them up, rather than having large horizontal bars and using vertical stirrups. Certainly, as he says in his paper, it does seem the economical thing to do, as the amount of steel in tension can be diminished towards the end of the beam. On the other hand, it has the drawback that in using a great number of bars one is liable to get imperfect concrete round those bars. When using a great many small bars, instead of a few large ones, you are bound to get those bars crowded close together, and the result is that the concrete may

not be quite sound in the very small spaces that occur between those crowded bars. I have myself cut out concrete in places where bars have been crowded, and found that small voids have occurred in consequence of the various steel members being too close together, and that being so, I always prefer, if it is at all possible, to have rather larger sections and keep them a respectable distance apart.

Once more, Sir, I would express our hearty thanks to Mr. Workman for all the information he has given us. (Applause.)

Mr. PERCIVAL M. FRASER, A.R.I.B.A. :—Mr. Chairman and gentlemen, I have very great pleasure in seconding a hearty vote of thanks to Mr. Workman. It is astonishing, considering the amount of concrete that we all see every week of our lives, the wonderful interest it holds for us. I have been quite held in rapture to-night to see the various works which have appeared on the screen, and we have all learned something again, I think, from seeing the works both in progress and completed, although only presented in pictorial form.

I notice Mr. Workman still uses the hackneyed expression, "This comparatively new material." I do ask that we members of the Concrete Institute should drop that to some extent now. It may be new in the number of years, but surely we are fairly old in our experience of it now. I do not think any subject has been so closely attacked and so minutely dealt with in all its details, practical and scientific, as reinforced concrete.

I have made a few notes, Sir, in the dark, and I have, therefore, some difficulty in reading them. (Laughter.) With regard to the comparative methods of the cranked bar and the stirrup as for tension strains, I am a very strong advocate of the stirrup form of construction, both from the point which Mr. Wentworth-Sheilds just mentioned with regard to surrounding the whole of the members thoroughly with the mixture, and also from, I think, a far more important point, that cranked bars are most difficult to construct. We have seen on the screen to-night the members formed of top and bottom rods and stirrups, slung up by a crane and

put into position in a way that, I think, would be absolutely impossible with a cranked bar. That is one advantage. It must be a great economy to handle a heavy beam 40 ft. long by means of a crane, and it suffers not a whit by being handled in that way. Two workmen can carry an ordinary bar with stirrups very comfortably indeed and drop it into position, and if properly made by winding the stirrup round the top and bottom rods, it can be handled and dropped about in a most merciless manner with very little deterioration. Another objection I have to the cranked bar is that you cannot use this economically where there is no slab forming a T to take up the compression.

It has been very interesting to see the photographs of the works in Jamaica. They are among the few buildings existing where concrete is perfectly treated as material fit for an elevation. The effect is obtained, not by facing up with stone or brick but by getting magnificent effects of light and shade and by a general charming proportion. In the case of the Hostel, I think at Birmingham, we have seen a photograph of a slab being concreted, the top of which was running with water. I venture to suggest that the concrete on that occasion was far too wet.

Mr. Workman says that rods are turned up at the ends to prevent them slipping in the concrete in consequence of the new rules of the Joint Committee of the Royal Institute of British Architects. I cannot conceive of rods slipping in concrete myself. I have never heard of a definite case of such a thing happening, and the only way I can look on a rod being turned up at the end is as a sort of factor of safety against the rod being painted or greasy, when it certainly would not stick.

I am driving a few piles next week which are on the Coignet system. It is interesting to note in this connection that I received the order to make these piles on Monday, and owing to the able co-operation of Messrs. Coignet and the contractor the seven piles were ready on Friday evening the same week. These piles are 28 ft. long and 12 in. in diameter.

Mr. Wentworth-Sheilds omitted to mention, in the case of M. François Coignet's roof on his Paris house, that the concrete there was lime concrete ; and,

in spite of this fact, the steel was found absolutely free from rust.

[MR. WENTWORTH-SHEILDS here interposed that there was a certain proportion of cement also used.]

I must say, from my experience, that reinforced concrete, waterproofed with one of the many compounds now on the market, gives good results. I have constructed a small flat roof (not on the Coignet system); it consisted simply of hoop-iron placed on edge. With regard to the water getting into this flat, it had a mixture of Medusa Compound in the upper two inches, and it is absolutely watertight. It is quite flat, and contains two inches of water, the outlet being above the main level. I am also constructing at the present moment roofs covering about 70,000 ft. There is a 3-in. fall in 90 ft. in each direction, and no other method is taken of covering these roofs except this waterproofing compound. I have nothing further to add, except to endorse the vote of thanks proposed by Mr. Wentworth-Sheilds. (Applause.)

MR. CHARLES F. MARSH, M.Inst.C.E. :—I have nothing very particular to say, but I am afraid after the last speaker's remarks that there is a necessity to say something in defence of reinforced concrete. It appears that Mr. Fraser prefers vertical stirrups to inclined stirrups.

MR. FRASER :—Not inclined stirrups.

MR. MARSH :—Please correct me, I want to know.

MR. FRASER :—I did not use the expression "inclined stirrups" at all; I do not know them at all.

MR. MARSH :—Well, inclined bars. I do not quite see the reason for preferring vertical reinforcement. It seems to me that the inclined bars are certainly equally efficient, if not more so.

There was also a statement made that the round bar never slips through concrete. Well, of course, I think it is generally recognised that it is necessary, or it is advisable, at any rate, to do something at the end of your bar, if you are reinforcing a beam, to make some sort of a security to the concrete, so as to counteract any tendency of the bar to slip, and I

think cases have been known of bars actually slipping through the concrete. I quite agree with Mr. Wentworth-Sheilds in not liking the form of the Coignet bent-up reinforcement owing to the fact that all the bars are tied close together, and there is not sufficient room between for the concrete to get properly round them.

I noticed one thing in the paper. Mr. Workman said that one advantage of the round bars was that they were preferable to any other bar from the point of view of adhesion. I do not know whether he refers to the tendency to slipping. Of course, it is hardly fair to any other form of reinforcement, such as, for instance, deformed bars, to say that round bars are better than they. The deformed bar offers more resistance than the plain bar from the point of view of sliding through the concrete, but the plain bar, properly dealt with, offers quite sufficient resistance in all ordinary cases.

There is another point of mere correction in the paper. Mr. Workman said that the big beams in some factory were parallel to the windows. I think he meant at right angles to them.

Mr. WORKMAN :—Yes, at right angles.

Mr. MARSH :—I do not think I have got anything else to say.

Mr. D. G. SOMERVILLE :—I do not know that I have anything to say about the matter, but I was rather interested in Mr. Fraser's statement that there were piles ordered on a Monday and ready to be used on the Friday night. I have made a good many thousand concrete piles——

Mr. FRASER :—They were ordered on the Monday and ready on the Friday.

A MEMBER :—Was it the following Friday?

Mr. FRASER :—No, we never drive piles on a Friday.

Mr. SOMERVILLE :—After that I will sit down.

Mr. E. FIANDER ETCHELLS, F.Phys.Soc. :—Mr. President and Gentlemen, I have listened with interest to the paper, and while the slides were on the

screen I was very much interested in the background of the pictures. It seemed like a holiday tour round Great Britain, and a visit to the West Indies, and I very much enjoyed it. I was also very pleased to notice that the author says that the specialists adopt the particular method of reinforcement which they think best suited to their purpose. I am glad that is stated, because it will correct a very erroneous impression that the specialists think best of the system which they have adopted. Of course, if they did, it would only be natural, because that was the system which they had studied most and had most experience of its good points, and in which they had most opportunities of remedying the bad points.

On page 3 it is stated that a round section produces the minimum amount of metallic contact between the various bars that form the units or trusses. That statement might be corrected, because square bars standing corner on corner, *i.e.*, with the diagonals running in the same straight line, would afford a still greater amount of space for the concrete in between the two bars. The angle of concrete would be better, if not quite so sharp. Of course, on the other hand, there may be disadvantages of adhesion against a flat surface; I am not oblivious of that possibility.

With regard to the suspended floors, they are most interesting, and they show one of the new developments of this form of construction. One of the finest instances in London is at Victoria Station, where a concrete platform is suspended, but there it is suspended by steel rods slung on steel girders.

Another very interesting illustration was a building with flying buttresses and a gallery outside. That was a remarkably good building, and looked very well. It reminded one of a building which is much praised, the King's College Chapel at Cambridge, where there are somewhat similar buttresses and the same spaciousness of windows. The detail was not the same, but the general idea was equally striking in both cases.

Another good illustration was that of a bridge at Inverness. That bridge seemed to be well designed and very well adapted to its purpose. One of the

noticeable features was the narrowness of the piers in the direction of the stream, so that the waterway was barely restricted at all. It is quite possible, however, that the open framework of the thin supports might tend to catch floating timber or trees. If that should happen the architects, or the persons responsible for the maintenance of the structure, could easily fill in that framework with ordinary mass concrete, and thus obviate the difficulty.

With regard to the bunker in which 2,000 tons of material were suspended, we may take it for granted that that was really suspended on steel rods buried in the concrete. It would be an advantage and of interest if the details showing the main reinforcement could be given in the TRANSACTIONS, so that we might see how such a heavy load is suspended.

Coming to one or two remarks of Mr. Fraser's, I should like to defend the author's statement in which he describes reinforced concrete as a comparatively new material. It is comparatively new, because woodwork was used round the Swiss lakes about six thousand years ago. In Egypt five thousand years ago they were well acquainted with brickwork. Two thousand years ago they were using concrete in Rome. Forged iron was used a thousand years ago in Germany. Rolled iron was used in Great Britain four hundred years ago, although it is at a later date that it was generally adopted and steel substituted. With the exception of one or two reinforcements with bronze, nearly all the reinforced concrete work of the world has been done within the lifetime of some of our senior members. Having regard to the long history of Structural Engineering and the antiquity of the art of building, reinforced concrete *is* comparatively new.

THE CHAIRMAN (Sir HENRY TANNER) :—Before putting this vote of thanks to you I should like to express my appreciation of Mr. Workman's address, and also of the very excellent series of photographs which he has shown, which make the paper far more interesting than papers usually are.

In regard to super-loads on floors, there is no doubt that what Mr. Workman says is absolutely correct. People do estimate the super-load at very much more than it is ever likely to be. We fixed $\frac{3}{4}$ cwt. for the

post-offices referred to, after having experimented on the subject. I had a considerable area of floor filled up as high as was reasonable with full parcel baskets, perhaps about 12 ft.; that is much more than we are likely to get on any floor of that sort, and it was found that the average load was well within the $\frac{3}{4}$ cwt. provided for.

As to roofs, I have never had any trouble with a flat roof of concrete. I have always covered them with asphalt, but you cannot lay the asphalt in too great widths. I think if you have asphalt without some means of expansion and contraction in spans of more than 40 ft. you are sure to get trouble; so what I have done is to make a small mound in the middle, as it were, like a roll of lead, when it has opportunities of drawing out of the internal angles.

Those buildings at Jamaica are of very considerable interest; they are rather new in design and in architectural treatment. Probably the plans of the internal arrangements have some effect upon this. With those remarks I propose to put the vote of thanks. I am sure you will carry it by acclamation (Applause.)

Mr. WORKMAN (replying to the discussion):—Mr. Chairman and gentlemen, I must first of all thank you very much for your very cordial reception of my paper, and I wish to thank Mr. Wentworth-Sheilds and Mr. Fraser. I now propose to take up some of the points of the various members who have been kind enough to make some remarks.

First of all, Mr. Wentworth-Sheilds has asked me to describe the driving of the piles at Bristol. These piles were not driven with a helmet; they were driven by means of a wooden dolly 18 in. in height and made of elm, the top and bottom of the dolly being encircled by a steel band in order to prevent it from splitting. Underneath the dolly sawdust was placed on the top of the pile, and held in by means of a little casing of sheet-iron to prevent it from flowing out; the wooden dolly was placed on it. The sawdust, however, after a few blows, was found to get absolutely as hard as the wood of the dolly itself, so we had to use something else. The next thing resorted to was coils of rope made into a kind of little mat and placed on the top of the wooden dolly; then the

steam hammer was placed on the top of the wooden dolly. In this way the piles were driven without any difficulty whatever. I have been informed lately that there is an advantage in driving with a helmet. We have never used any helmet, because it is rather an expensive apparatus, and so far we have always been able to do without it ; but I am informed by contractors—and I give you the benefit of this information —that they believe the helmet is an improvement. That is all I can say about it. I do not know in what way it is an improvement ; I am told it prevents the head from being battered, but I have never seen much objection to the head of the pile being battered, because, as a matter of fact, in most cases you have to chip the concrete at the head of the pile to unite it to some beams or some foundation supporting the columns.

Now, with regard to Mr. Wentworth-Sheilds's request that I should describe the reinforcement of the four central pillars for the sorting-office of the Western District Post Office, as far as I remember it was composed first of all of four bars in each corner of the pillar and two intermediate bars between those four bars, so that inside the column you would have altogether eight bars of about 1 in. in diameter, and those bars were bound by means of $\frac{1}{4}$-in. helical ties placed about 6 in. apart.

I would take this opportunity to mention a thing which may be of interest to those dealing with very large columns in reinforced concrete. It is necessary when designing a very large column to have a concentric row of bars in the centre of the pillar, and I remember very well that the question was discussed when we designed the reinforcement for these particular pillars at the Western District Post Office as to whether there would not be some advantage in placing the bars in the centre as well as on the periphery of the pillar. We came to the conclusion, however, that we could do without that. We simply placed the bars in the manner I have described, and, as a matter of fact, this proved quite satisfactory, not only in this case but in many others. I may say here that these are by no means the heaviest pillars which I have had to deal with. For instance, all the pillars in

the second tobacco warehouse support 300 tons, and they were constructed in the same manner as those of the Western District Post Office.

MR. WENTWORTH-SHEILDS :—Is it for constructional reasons that you have got a concentric row of steel rods?

MR. WORKMAN :—It is thought that if another concentric row is placed in the centre of the pillar, it reinforces the core of the concrete pillar better than if you place all your steels on the periphery only.

Now, concerning the suspended beams, I have endeavoured in my paper to describe how those beams were suspended to an upper beam actually above the floor level, but I admit that on reading my paper over again I was astonished to find how difficult it was to make it clear without showing drawings, and I wanted as much as possible in this lecture to avoid showing drawings, because I wanted to show you photographs only. I will try to briefly explain how these beams were suspended. The suspended beams were placed at right angles to the beam above, so that these lower beams were bodily supported by means of straps or stirrups hooked on to the tension bars of the lower beams, and penetrating into the upper beam, and hooked into these. Of course the straps or stirrups suspending the lower beams had to be calculated of sufficient strength to carry, not only the dead load of all this mass of flooring with the beams, but also the superload, and as I said in my paper, although I endeavoured to find out whether anybody else had ever done this before, I could not find that anybody had. Mr. Etchells mentioned, I think, that he had seen at the Victoria District Railway Station a platform suspended in that manner. I have seen it, but that is in steel work, while what we were doing was reinforced concrete, and, as I say, I could not find that it had been done before.

MR. WENTWORTH-SHEILDS :—Excuse me ; were the suspending links passed right over the upper reinforcement, or an upper beam, or merely over the tension reinforcement of the upper beam?

MR. WORKMAN :—No, the straps were simply bent over in the concrete like a hook, simply to form a sufficient anchorage in the concrete.

MR. WENTWORTH-SHEILDS :—About half-way up the beam or something like that?

MR. WORKMAN :—Right to the top. Now, concerning the covering of flat roofs, of course, with roofs in reinforced concrete, if the covering is not properly treated, these roofs are very apt to give trouble, and as I am aware the best way is simply to cover them with asphalt. M. Coignet is of opinion that asphalt is not a good material to cover flat roofs, because the mineral oil contained in the asphalt is liable to evaporate after a certain time, the asphalt becomes a dry, dusty material, which then cracks and lets the water through the concrete, unless the concrete itself is not a sufficiently strong mixture to be water-proof.

Concerning my remark about the vertical bars resisting horizontal shear and the horizontal bars resisting vertical shear, all I can say is that that is what we consider is taking place in these beams. Of course, I am quite aware of the fact that these efforts are maximum at the neutral axis, and with very deep beams a certain number of small bars are placed at the neutral axis at the point of penetration of a beam into a pillar, but generally the concrete is quite sufficient to take a considerable amount of the shear itself.

In answer to Mr. Fraser's question, there is no doubt about it that the reinforced concrete is a comparatively new material. It is only within the last fifteen years, I think, that it really has been used extensively, and of course it is growing in use gradually, but at the same time, when we compare it with brick and any other form of construction, even steel work, we can only say it is a comparatively new material. I think Mr. Etchells has come to my rescue and defined the situation by citing examples of antediluvian works in masonry, but there is no doubt about it, although reinforced concrete is making rapid strides, we cannot say it is very old.

Concerning the cranked bars and the frameworks

made with vertical stirrups, I know Mr. Fraser prefers vertical stirrups, and he suggested that the frame which was shown in the photograph could never have been lifted if it had been made of cranked bars. I am sorry to undeceive him, but that particular frame is made with cranked bars. The bars being hooked on to the top bar, of course it is quite possible to lift the unit.

Mr. Marsh also made some suggestions about the two different methods of making reinforcement. The reason the system of beams with cranked bars is preferable to the system of beams with horizontal bars is because the beams made in this manner are more elastic.

I am sorry that time does not allow me to discuss any of the other points, nor to give you a description of the reinforcement of the bunkers at Kinlochleven. The plans are so very complicated that it would be absolutely impossible for me to show them on the screen and make you understand without going into a very detailed description. I must again thank you for your cordial reception.

THE CHAIRMAN :—The date of the next Ordinary General Meeting will be January 11th, at 8 p.m., when discussion will take place on the Report of the Reinforced Concrete Practice Standing Committee on the Standardisation of Drawings for Reinforced Concrete Work. An Interim Report of the same Committee on "Consistency of Concrete" will also be submitted for discussion.

The meeting then terminated.

TWENTY-SECOND ORDINARY GENERAL MEETING

THURSDAY, JANUARY 11, 1912

THE TWENTY-SECOND ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held on Thursday, January 11, 1912, at 8 p.m., in the Lecture Hall at Denison House, 296, Vauxhall Bridge Road, London, S.W.,

MR. F. E. WENTWORTH-SHEILDS, M.Inst.C.E. (Vice-President of the Institute), in the Chair.

THE CHAIRMAN: -Gentlemen, I have first to read out to you the names of those who have applied for membership of the Institute.

The following were then duly elected members :—

MR. PETER B. JAGGER, Director of the Improved Construction Company, Westminster.

MR. JAMES M. KESSON, of Alwen Reservoir, Cerrig-y-druidion, near Corwen, North Wales.

MR. L. S. RUDMAN, Civil Engineer, London.

THE CHAIRMAN (Mr. WENTWORTH-SHEILDS) :— I will now ask Mr. Vawdrey to read to us two very interesting Reports which have been prepared after much careful thought by the Reinforced Concrete Practice Standing Committee of this Institute, of which he is Hon. Secretary. The first one deals with "The Standardisation of Drawings." This Report, I may mention, has already been published in the TRANSACTIONS of the Institute, but this is the first time we have had an opportunity of discussing it. The second is perhaps even more interesting, and is on the very important question of the "Consistency of Concrete." Mr. Vawdrey, as Secretary, has taken a lot of trouble

in connection with these reports, and I will ask him to read them, and to give us any views on the subject that he has himself.

Mr. R. W. VAWDREY, B.A., Assoc.M.Inst.C.E., then read extracts from the Report on "The Standardisation of Drawings of Reinforced Concrete Work."

Continuing, Mr. VAWDREY said :—In connection with that Report, there are one or two remarks I should like to make. It is clearly desirable, I think, that some sort of uniformity—as much as possible—should be attained in drawings, but I suppose all rules are only meant to be broken, and it is quite impossible for any large drawing-office to insist on any such rules as those which have been suggested being absolutely adhered to. The object of the Report is to encourage the same style and methods rather than to insist upon, or attempt to recommend the insistence upon, any details.

My own personal opinion is that anything in the nature of colouring on drawings for reinforced concrete work, which are necessarily more or less intricate, should be avoided, and I should like to lay, personally, more stress on that point than is made in the Report. The same personal opinion applies to the marking to show concrete. So far from making matters clearer, my own experience is that it makes matters very much the reverse to attempt to show concrete by dots or hatching or anything of that sort, especially with a view to reproduction of drawings. I think everything should be either in black and white or solidly blacked in.

The system of symbols, I think, is a good one, but the whole object of a system of symbols such as we suggest is that they should be perfectly intelligible to everybody. That, I am afraid, would not be the case if they were suddenly taken into general use at the present moment ; but in any drawing-office in which a particular system of symbols, such as that suggested, can be used, the advantage in saving of space on the drawings and saving of time is very marked.

The same thing applies to standard lettering. I am afraid it is quite impossible to hope that any standard

lettering can be universally adopted, but if in any particular office that can be gradually brought about—the process must be gradual—it certainly must be a very great advantage.

The next Report I am to read is the Interim Report of the Reinforced Concrete Practice Standing Committee on "The Consistency of Concrete."

INTERIM REPORT OF THE REINFORCED CONCRETE PRACTICE STANDING COMMITTEE ON THE CONSISTENCY OF CONCRETE.

A circular letter of inquiry on the subject of the Consistency of Concrete was addressed to the members of the Concrete Institute, in which it was suggested that a specification as drafted would be of service, pending experiments and tests that ought to be made to determine the exact proportion of water to be used in concrete in order to obtain the best mixture. This specification, as now slightly modified by the Committee, is as follows :—

> **Consistency of Concrete.**—For mass concrete the quantity of water added to the other constituents shall be sufficient to make a plastic mixture which, after thorough ramming, will quiver like a jelly.
>
> For reinforced concrete the quantity of water added to the other constituents shall be such that the plastic mixture is capable of being rammed into all parts of the moulds and between the bars of the reinforcement.
>
> *Note*.—In dry or hot weather the quantity of water shall be increased in order to allow for evaporation.

Fifty-eight replies were received, from which a number of extracts are appended hereto.

The replies have been carefully considered by the Reinforced Concrete Practice Standing Committee, who have come to the following conclusions :—

1. It is inadvisable to lay down any definite rule as to the percentage of water to be used in mixing concrete, owing to the varying conditions which obtain. The proposed specification is difficult to

improve upon, and seems to meet with general agreement.

2. The strength of concrete apart from any reinforcement increases as the amount of water used in mixing is decreased, this being more particularly the case during the earlier stages of the maturing of the concrete. Eventually the wetter of two mixtures will approach more nearly to the drier in strength.

3. In reinforced concrete, particularly in such portions as may contain a large amount of reinforcing bars or the like placed closely together, it is essential that the concrete should be sufficiently wet to pass between the reinforcing bars, and to thoroughly surround every portion of the steel. This should be ensured even at the expense of having the concrete wetter than would otherwise be desirable.

Where the reinforcement is not very closely spaced it is unnecessary for the concrete to be so wet.

4. Other conditions being the same, the drier the concrete the more quickly will it set and mature. This is of importance when there is any danger of green concrete being attacked by frost.

5. The wetter the concrete the greater is the tendency to contract during the process of setting and maturing. Appreciable contraction may sometimes continue for a period of several years.

6. The Committee is divided as to the advisability of determining by some means of mechanical test the exact degree of "wetness" or consistency of concrete after mixing. If some scale of consistency were adopted, it would be possible to specify that concrete for any particular portion of the work should be of such and such a consistency, after mixing. This would not, of course, be at all the same as specifying that any particular amount of water should be used in mixing such concrete, owing to differences of atmospheric temperature, aggregate, etc.

The advocates of the institution of some such scale of consistency are of opinion that the Concrete Institute should carry out tests on the subject.

SUMMARY OF REPLIES RECEIVED.

1. Several correspondents advocate the consideration of the results of tests before any rule is arrived at.

2. One correspondent suggests that a table should

be given showing the maximum difference found in practice with different aggregates in the usual proportions and under different conditions, the quantity of water to be stated in gallons per cubic yard and the moulds assumed to be of soft wood. The form of table is as follows :—

PROPORTIONS OF CONCRETE.

Gallons of water per cubic yard of materials.

	Sandstones, Oolites, "Common" Brick.				Granites and Hard Limestones.	
	Aggregate, Dry.		Aggregate, Wet.			
	A.	B.	A.	B.	A.	B.
Dry weather ...						
Wet weather ...						

A = for getting into corners and sticking to steel all over to prevent corrosion.
B = for strength in masses of concrete.

3. Some correspondents point out that the quantity of water required might vary with the character of the cement, namely, whether "quick" or "slow" setting.

4. A correspondent points out that in one case 25 to 30 gallons of water per cubic yard of concrete has been advised, and in another case 21 to 24 gallons per cubic yard of dry material.

5. A second correspondent uses one gallon of water to one cubic foot of dry material where the aggregate is crushed Thames ballast ; in his case, when the temperature has been above normal, it has been necessary to increase the amount up to 25 per cent. of the above-stated quantity, and when the reinforcement is heavy and ramming difficult, a further supply of water is necessary and $1\frac{1}{2}$ gallons may be needed.

6. A third correspondent says that usually about 22 per cent. of the total volume of cement and sand or 20 per cent. by weight of these are usually taken

for the quantity of water, but points out that about 15 per cent. by volume is required to enter into chemical combination with the cement and sand, and the rest is lost by evaporation, leaving in its place undesirable voids in the mass.

7. One correspondent suggests that the provision as to addition of water in hot and dry weather is unnecessary, for under such circumstances a certain increase would be automatically required to produce plasticity, and the loss should be prevented and not counteracted by means which tend to impair the quality of the concrete. He suggests the substitution of the following rule as sufficient to cover all cases :—

"The quantity of water added to the cement and aggregate mixture shall be just sufficient to produce a plastic mass after thorough and complete mixing."

8. Another correspondent would prefer to substitute the following wording for the clauses put forward :—

"For mass concrete as much water should be added as the mixture will take without spilling away or working up to the surface when the concrete is being conveyed to its destination.

"In the case of reinforced concrete if after ramming into position the water works up to the surface, the quantity may be considered excessive. Short of this, however, as much water as possible should be added."

9. A correspondent requires the condition "that when the concrete is thoroughly rammed into place water shall only just appear on the rammed surface."

10. A correspondent suggests the insertion of the word "light" before the word "ramming," as the heavy way in which this is carried out, especially in reinforced concrete, often results in the boards of which the moulds are made springing apart and so allowing the water and cement to ooze through the joints and detract from the final strength.

11. One correspondent suggests adding in the first paragraph the words "and not more than sufficient" after the word "sufficient."

12. It is suggested that emphasis should be laid on the fact that the mixture must only quiver like a jelly *after* the ramming has been completed and not

before. It is also suggested that it might be advisable to state that where absorbent coarse materials are used great care should be taken to let them absorb all the water they require before being mixed with the cement, or having arrived by experiments at the amount of water which the aggregates will absorb that extra amount of water should be added at the time of gauging. It is thought, however, that the former practice would be preferable.

13. One correspondent points out that the words "quiver like a jelly" would apply to a small aggregate and gentle continuous ramming, but that a larger graded aggregate would not show the same result.

14. One correspondent does not favour ramming of concrete, preferring "a plastic mixture of the utmost possible density, which will flow into position in the moulds and round and in contact with the reinforcement (if any) without ramming other than consolidation aided by iron bars or spades."

15. Two correspondents point out that the danger to be guarded against where a plastic mixture is advised, is one of loss of homogeneity caused by repeated ramming resulting in the larger parts of the aggregate going to the bottom, leaving the fine particles at the top.

16. Another correspondent suggests that to the rule for reinforced concrete should be added the words "but in no case should the water be so much in excess as to cause the concrete to be of such consistency that when the mould is filled and rammed it has a distinct tendency to act as a semi-fluid under the punner."

17. A correspondent objects to the watering down of concrete to the consistency of slurry in order to make it run into the centering and round the steel, for the average centering is not sufficiently watertight to prevent a certain portion of the finest material escaping. He thinks that attenuated dimensions in reinforced concrete work should be avoided, so as to do away with the necessity for making the concrete so liquid.

18. It is suggested that the specification should state that for reinforced work the concrete should not contain so much water as to cause a large quantity thereof to exude during ramming.

19. It is pointed out that with reinforced concrete

pipes it might be found impracticable to ram the mixture into all parts, and for such class of work it would have to be of such consistency as to run.

20. Several correspondents direct attention to the prevention of drying in hot climates. The procedure adopted by one correspondent is to use very little more water in the original mixture, but to shade the work from the direct rays of the sun for the first twenty-four hours. Then if in small blocks they are totally immersed in a shallow tank of water, or if in mass concrete the work is covered with wet sacks or reed matting which is kept at the point of saturation. In either case the concrete is sprayed with water twice a day for about a fortnight.

21. Another correspondent in hot and dry weather waters the concrete two or three times daily for a week or so.

22. One correspondent suggests adding the words "and absorption" after the word "evaporation." He thinks that in hot weather it is possible the false work should be watered on the outside unless a little extra water be added to the concrete.

23. A correspondent desires to call attention to the legal aspect of the case, which would probably be raised in the case of a dispute, and that is the "goodness" or "badness" of the rule. For this reason he thinks the personal element must be entirely eliminated, and the rule or specification should be so framed that the results will be the same irrespective of the persons who shall do the work. He suggests the making of a wooden box, 5 in. wide by 3 in. deep and 6 in. long, with two 1-in. square steel bars arranged vertically and attached securely to one of the sides, which is to be hinged at the bottom to the remainder of the box so as to be capable of being opened. In use the box would be filled, then after a specified length of time turned with the side carrying the bars uppermost and opened, when it would be found whether the concrete kept the correct form of the mould. He suggests that two boxes should be used, and that the Committee should consider—

(*a*) The size and shape of the boxes.

(*b*) The time before the first box is to be opened (minimum).

(*c*) The time before the first box is to be opened (maximum).

(*d*) The amount of ramming (preferably none).

(*e*) The degree of fulness of the boxes.

24. Finally, a correspondent calls attention to a different method of mixing concrete which he advocates. He first thoroughly mixes one part of cement with, say, two parts of very fine clean sand, using clean water enough to make a mixture of the consistency of thin cream, and then remixes with three parts of wet sand coarser than the first. This total mixture of 1 : 5 is then mixed with, say, five parts of broken stone. He asserts that with the proportions mentioned, namely, 1 : 10, the same strength is obtained as with that of 1 : 7½ concrete of the usual class.

The principle of the method is the obtaining firstly of thorough contact of the cement with every grain of the fine sand, which is rendered certain by the large proportion of the cement used, thus ensuring that every grain of sand is completely enveloped in the liquid mixture. A mixture of this consistency is well calculated in the remixing to adhere to all the wetted grains of the coarser sand, which will take up the superfluous cement and water and leave only that which sticks to the surface of the grains of the fine sand. He thinks that the fine sand mixture will thus more nearly fill the voids of the coarser sand than happens in the usual systems of mixing, where many grains of sand get washed by the water, while in other parts many grains of cement are found stuck together.

For a stronger concrete the mixture would possibly be 1 part of cement to 1½ parts fine sand, and this remixed with, say, 2½ parts of sand and 3 parts of broken stone. Another mixture would be 1 part of cement to 1 part of very fine sand ; this remixed with 2 parts medium sand and again remixed with 3 parts very coarse sand ; all finally remixed with 5 parts broken stone of different sizes.

This system only requires about the same amount of labour as the common one, because the liquid mixture is small in bulk and quickly made.

Mr. Vawdrey continued :—I would point out that the procedure adopted in this case was for the Secre-

tary of the Concrete Institute to issue circular letters to all members, and, I believe, to some other persons whose opinion was thought to be of value, asking them what their practice and advice was with regard to consistency, the amount of water which should be added to concrete in both mass concrete work and reinforced concrete work.

MR. VAWDREY then read the Report of the Committee down to the paragraph concluding with the following words : "who have come to the following conclusions," and then interpolated :—

Roughly, the Committee is unanimous in these general recommendations. They are also based, not only on the personal opinions of the Committee but on the great majority of the replies received. In other words, the great majority of the replies received from the general members of the Concrete Institute coincide with the views of the members of the Practice Committee.

MR. VAWDREY then resumed the reading of the Report, commencing at the words, "It is advisable," and continuing down to the words, "fulness of the boxes," at the top of page 82, where he again interpolated :—

That suggestion corresponds more or less in some way to the suggestion the Committee themselves made in Clause 6, that some form of test should be devised by which the consistency of the concrete should be obtained.

Mr. Vawdrey then continued the reading of the Report to the end, after which he said :—

I should like to point out that the chief difficulty that the Committee experienced in discussing this question was that of describing the degree of wetness or dryness required. Of course, the amount of water to be mixed with the concrete cannot possibly, I think, be defined. I think that is universally admitted. I mean, to mention a percentage, so much per cent. of water, as a general specification would obviously be absurd. It must necessarily vary with the class of materials used, with the quality of the cement, with the temperature of the atmosphere during the actual process of mixing, with the amount of ramming which

has to be performed, and with the intricacy of the work. There are all sorts of conditions which must vary, but it might be possible—I think it would be—to devise some easy method of describing the degree of plasticity—if I may use the expression—which is desirable in the concrete after mixing. That is what is suggested in one clause of the Committee's recommendations.

I may say that the Committee was very much divided on that question. A good many seemed to consider that it would be quite impossible to devise any such scale of consistency, and that even if that were done it would merely lead to difficulties on the part of the contractor, who would be expected to adhere to a particular scale on every part of his job—in fact, that he would have a lot more tests to pass. But that is not my view at all. The whole object of such a scale of consistency is to my mind that, if an engineer or an architect wants to specify the degree of wetness or the consistency of the concrete in one part of a building, he may be able to do so easily. He may be able to say that in the beams, or any particular portion of any beam, he would like the concrete of such and such a consistency.

My own point of view, therefore, is that it would be very useful for this Institute to make some sort of tests, which would possibly be adopted universally as a means of describing the consistency wanted.

Correspondent No. 10 remarks, referring to the ramming, that he wants very light ramming only. Personally, I do not agree with that at all. I think that too much ramming cannot be done, and his objection that heavy ramming often results in the boards springing apart and allowing the water and cement to ooze through the joints is not a fault of the ramming, but a fault of the shuttering. The shuttering should be so constructed that it can take proper ramming.

Correspondent No. 13 remarks that only concrete mixed with a small aggregate, and on which gentle continuous ramming has been used, will quiver, but that with a large aggregate you cannot get the quivering. I entirely disagree. In a large mass of concrete you certainly can get the quivering condition

which everybody seems to think desirable, even though the aggregate is very big. Of course, if you have a small reinforced concrete beam, and a few big stones in it, you will not get any quivering because the stones will wedge themselves from one side of the beam to the other, but in a heavy block of mass concrete you will get exactly the same appearance as in a small mass of very much finer concrete.

In the same way, I disagree entirely with correspondent No. 14, who says he objects to ramming. I am convinced, both by theory and practice, that it is advantageous in every way to have thorough working and ramming of the concrete in reinforced concrete work, and in mass concrete work too.

Correspondent No. 24 raises a somewhat different point from that mentioned in the rest of the paper, namely, the proportioning of the concrete, but it is so very important that we considered it worth while to insert his remarks in this paper. I agree entirely with what he says, or rather, with the idea which underlies his remarks, which is, I think, that ordinary concrete is very badly proportioned. The strength of concrete obviously depends to a very great extent on the strength of the mortar. By mortar I mean the fine material in which the larger portions of stone are embedded and held together. An ideal concrete, I take it, would be one in which there would be no mortar at all, or practically no mortar. Of course, I am exaggerating now intentionally. The extreme on one side would be a lot of particles of broken stone which could be so accurately fitted together that there would be practically no voids between them. That condition might be obtained if a large number of regular cubes, for instance, of stone were accurately fitted together. The amount of mortar required in that case would be practically nil. On the other hand, the average regular stones show approximately 50 per cent. of voids.

The cost of the concrete can thus be very greatly reduced by the grading of the aggregate, so that the total amount of voids is very small. That enables the amount of mortar to be reduced, and it is quite possible to have a concrete consisting, instead of the 4 of stone, 2 of sand, and 1 of cement which

is ordinarily specified, say 4 of stone, $\frac{1}{2}$ of sand, and $\frac{1}{4}$ of cement. I have actually seen concrete, and I have made concrete, of those proportions, which has been quite excellent, but, of course, that is dependent entirely on the fact that you can obtain an aggregate which has such a very small proportion of voids as those I have mentioned. In ordinary practical work one has to use materials that can be easily obtained, and in most cases it is certainly a fact that the stone which one gets will have something like 50 per cent. of voids in it, in which case the proportions of 4 of stone, 2 of cement, and 1 of sand are about right. There is no objection, in my view, to greatly decreasing the proportions of sand and cement if the amount of voids is decreased by proper grading and mixing of the aggregate. That, I think, is the principle underlying the mixture suggested by correspondent 24.

With regard to the general question dealt with in the Report—the amount of water—I think the general opinion of the majority of correspondents, and certainly of the Committee, is that the use of a large quantity of water is to some extent a necessary evil in reinforced concrete work. With mass concrete, in which voids are not so harmful as they would be in reinforced concrete, it is, I think, undoubtedly possible to get considerably stronger concrete—at any rate in its early stages—by the use of a fairly dry mixture; but in reinforced concrete, although assuming one can be sure that no voids will exist, even in that case, too, it would be advisable to use the concrete as dry as possible; yet the risks of voids and improper contact of the steel with the concrete are so great that one is almost driven to use a concrete considerably wetter than would otherwise be desirable, and in many cases, such as the junctions of beams and columns, where there is necessarily a very large amount of reinforcement, it is practically impossible to use any sort of concrete otherwise than almost liquid grout or slurry as one of the correspondents calls it. Although one may be forced, in spite of one's wish, to use concrete of that nature in certain proportions, at any rate there are many disadvantages besides the corresponding weakness of the concrete.

One has been mentioned—that is, the cracking. It

does appear undoubtedly the case that the wetter the concrete is when it is moulded and placed in position, the more chances there are of contraction during the process of setting, and not only of setting but during the process of maturing.

In my own experience quite recently, I had a case in which contraction had obviously been going on in a floor of considerable area for three or four years, and is to some extent still going on. Of course, the amount is almost infinitesimal, but undoubtedly the movement of contraction is still taking place. I am not referring to a temporary contraction, but a permanent maturing contraction, and I think that is the general experience of members of the Committee (Applause.)

MR. L. SERRAILLIER, M.C.I. :—I have much pleasure in proposing a vote of thanks to Mr. Vawdrey for the trouble he has taken in the work of this Committee.

The only remark I have to make concerns the first paper : I believe there is a method of making sections by placing the tracing paper over the back of a book in which the cover is rough, and rubbing a pencil over the tracing. This will give the appearance of hatching and show up the section lines. The method is rapid, and allows of blue prints being taken.

AN HON. MEMBER :—Not on an ink drawing.

MR. SERRAILLIER :—On a pencil drawing ; but you can do it in pencil on an ink drawing as well.

THE HON. MEMBER :—On a blue print?

MR. SERRAILLIER :—On a blue print, yes.

THE HON. MEMBER :—Has that a good effect?

MR. SERRAILLIER :—Yes. The other matter I wished to refer to was the lettering. Mr. Vawdrey says the lettering should be as large as possible. Of course, the larger it is the more tendency there is that the appearance will not be good, unless you use stencil plates. I am very much in favour of using stencils in drawings, and not block printing. The larger the block printing is, the less regular it is, and the uglier it appears on the drawing.

Mr. S. BYLANDER, M.C.I. :—Mr. Chairman, it gives me very great pleasure to second this vote, and in particular to thank Mr. Vawdrey for the very valuable remarks he has added to the Reports.

Personally, I am most interested in the first Report as regards standardisation of drawings. From my experience in America I found that the Americans have gained enormous advantage over the rest of the world through their standardised method of producing engineering work. The thing that struck me most was the drafting-room, with standardised methods in great detail. Every office of good standing has a set of standard tables. These are used throughout the office by each member, and this produces uniformity in methods and design.

Further, the title of a drawing is always placed on the lower right-hand corner, which is found very convenient in case of reference, when one has, say, forty or fifty drawings in a drawer ; one can thus easily find the drawing wanted.

Another thing, which I believe is not quite realised, is that the Americans use mostly $\frac{1}{4}$-in. scale plans instead of $\frac{1}{8}$-in., as is used here. They therefore use 1-in. scale details instead of $\frac{1}{2}$-in. I believe that this has been introduced on the drawings, and therefore greater accuracy and clearness is required, and in consequence a greater scale is employed. I only wanted to mention this in connection with the Report, as it appears therefrom that the 1-in. scale would be best. Personally, I believe that for steelwork plans or reinforced concrete plans the $\frac{1}{4}$-in. scale is a better one, providing the size of drawing required is not unreasonable.

With regard to the $1\frac{1}{2}$-in. scale for details, I would prefer the 1-in. scale, because the architectural details in this country are usually made to $\frac{1}{2}$-in., and the simplest method of transferring from one scale to another is by doubling the size. Further, I think the 3-in. scale could be used wherever the 1-in. scale would not be sufficiently large, and as all drawings should be fully dimensioned scaling is not required.

With regard to the list of sizes of drawings, I believe it would be advisable to add something with regard to the size of order lists. That is a kind of

drawing which, I think, will very much be used in the future, much more so than hitherto.

A very convenient size would be a quarter of the smaller size mentioned in the Report—namely, 15 in. by 10 in. over all, or 14 in. by 9 in. within margin lines. You therefore would establish a standard of drawings of different sizes, obtained by halving the next larger size.

With regard to consistency of concrete, I think it would add very greatly to the value of this Report if a definite quantity of water could be determined for, say, London practice or English practice for the standard concrete now accepted—viz., 1 cement, 2 sand, and 4 crushed gravel. I do not believe that the quantity of water would need to be varied much under ordinary conditions.

Mr. Chairman, I thank you for allowing me to second the proposition. (Applause.)

THE CHAIRMAN (Mr. Wentworth-Sheilds):—The discussion is now open. We have heard two very interesting Reports, and I am sure we have all a good deal to say on one or both of them.

Mr. E. P. WELLS, J.P., M.C.I.:—Mr. Chairman, I had hoped this evening to see a very much larger attendance, especially as we combine in these Reports the standardisation of drawings and the consistency of concrete.

In reference to the first Report of the Reinforced Concrete Practice Standing Committee, it is practically a unanimous one. Of course, there are certain variations that one would have liked to have seen, but it is an impossibility to satisfy the views of all. Taking it generally, I think the Report is one which might be adopted in this country.

Personally, I do not like to see all drawings necessarily the same, as it to a very large extent causes individuality to disappear.

With regard to scales, taking the general type of drawing that one has to use, the $\frac{1}{8}$-in. is very good for plans so long as there are no complications whatever. If you have plain, straightforward work, then you can get on to the $\frac{1}{8}$th scale plan everything that is necessary in the shape of reinforcing, and there is sufficient room also to state what the beams are com-

posed of ; but if it is a case of varying spans, both of floors and beams, then I often find that the $\frac{1}{8}$th is too small, and I invariably adopt $\frac{1}{4}$.

With regard to elevations for walls, $\frac{1}{4}$-in. is sufficiently large practically to show everything, unless there happen to be any architectural features requiring to be incorporated into the reinforced work, when the $\frac{1}{4}$-in. becomes too small. For beams and columns I think, as a rule, the $\frac{1}{2}$-in. is ample, because all the reinforcing can be shown in thick lines, which, when reproduced, come out very boldly, especially in the ferro-prussiate prints.

For sections of beams and columns I prefer the $1\frac{1}{2}$-in. scale ; I have been in the habit of using it in all steelwork design for many years, as it makes multiples of $\frac{3}{8}$ths and $\frac{3}{4}$-in. At any rate, it is sufficiently large to show everything, and as a rule, I think, is preferable to the 1-in.

Occasionally I find it necessary to use full size where there is great complication in rods, and where practically grout has sometimes to be used you cannot do anything else.

As to the size of the sheets, I like to adhere to the Imperial size, but I never, if possible, get outside the Double Elephant. If I have to do so, then I get the Double Elephant breadth by the Antiquarian length.

A plan which I have adopted, and which comes in very handy at times, is to take some of the general work which is existing and put that in, in pencil, with the reinforced work in ink. The result is exactly the same as working in two colours, in red and black, and it distinguishes the new work from the old, and no mistake can possibly be made in the matter.

With regard to sections, and the question which has arisen about showing the concrete, I prefer it in all work, because once it is done there is an end of it. It is not as in the olden days, when one had to trace everything. Now one tracing is made, and it is always reproduced.

With regard to the last Report on the consistency of concrete, it is a very well-known fact that the drier the concrete, and the more it is rammed, the greater the compressive strength, but the whole resolves itself purely into a question of labour.

With regard to reinforced work, especially if there are a number of small members within a beam, it is not advisable to do too much ramming. Nothing is to be gained by it. If the mixture is made too dry, you will never get the proper adhesion between it and the steel. Therefore it is advisable to make the concrete of such consistency that practically when it is in a heap it will not run. This means that, if you use Thames ballast in your aggregate and Thames sand for the mortar, it requires about $7\frac{1}{2}$ to 9 per cent. of water, according to the time of the year, which is required to be added ; but if bricks are used, or sandstones, or oolites, which will take up about 10 per cent of water, then it is advisable to let the aggregate take up all the water that it will contain before it is mixed with the sand and cement, which ought then to be mixed dry, after which about 6 to 7 per cent. of water is all that is necessary to give an absolutely perfect consistency to the concrete.

With regard to the bricks, it is an absolute necessity to wet the bricks first if you require to get a really good homogeneous concrete.

There is one point, while I am on the subject, which I may take the opportunity of saying, and that is with reference to the use of Fletton bricks in concrete. I wish to call the attention of every member of the Concrete Institute to the great danger he runs in using Fletton bricks in the making of concrete. It only came to my notice about two or three months ago in some work that I designed for a gallery to a church, and within a fortnight after the gallery had been finished it started to blow all over the place, and in every case where it was opened out it was found to be a piece of Fletton brick that was the cause. Last week at the meeting of the Committee, Mr. A. C. Davis showed some photographs of concrete which had been made of Fletton brick, and within one week after being made it had blown all over the place and disruptured the concrete. Analysis of the Fletton brick disclosed an enormous excess of sulphuric anhydride.

Mr. Davis had the same experience with the bricks made from the same formation, and they had disrupted the concrete. There is no doubt about it, now that Fletton bricks are becoming generally used in London,

that one will have to be very careful, if brick concrete be used, that one does not get the Fletton bricks mixed up with other aggregates.

AN HON. MEMBER :—Might I ask if they were new bricks, or bricks which had been used?

MR. WELLS :—I could not tell you what age the bricks were, but Mr. Perkins, the District Surveyor for Holborn, told me that he had seen a heap of Fletton bricks that had been in the open air for six months, which had simply crumbled to pieces and been blown and disrupted in every quarter.

I have not only heard this from two or three sources, but from more, and in speaking the other day to a foreman of works, he said it is a known fact that Fletton bricks put into concrete will always blow. I believe that the clay that surrounds Peterborough has intrusions of the blue lias formation which is found between Rugby and Cambridge, and this would account for the blowing. An excess of lime has got into the brick, and it has not been properly calcined. Of course, that is a matter for experts to go into, but from what I have seen lately it seems to be a very dangerous practice to use any Fletton bricks in concrete without properly examining the same.

I intended at the last meeting to say something about it, but now the opportunity has cropped up I think it is as well to let it be known, because others may have something to say on the matter, and it will never do to go on making reinforced concrete, or even mass concrete with any material where we know there is likelihood of mischief taking place.

With regard to concrete made like slurry; there is an ernormous difference in the strength. I made some experiments a few years ago, where, with one specimen which was made with an excess of water and was little better than slurry in consistency (it ran all over the place and it had to be poured into the mould), at the expiration of three months the crushing resistance was 180 tons a square foot, whereas a proper plastic mixture of concrete made at the same time went up to 300 tons a foot.

As I have said very often before, with regard to the amount of moisture, it all depends. If you want

to get a cheap concrete and save your labour, you must let the water do the work. If you are not particular as to labour and can spend the money, then lessen the water and put in the labour. Then you will get greater strength, especially in short periods. You will get a strength in seven days with a very dry mixture which would take a month with a moderately wet one ; and if you want it to harden quickly, then the drier it is made, and the more ramming it gets the better, especially in wet weather. (Applause.)

MR. D. B. BUTLER, A.M.I.C.E. :—I should like to confine my remarks more particularly to the Report on the "Consistency of Concrete." It must be borne in mind, I think, that in adding water to concrete, the water has two functions to perform. The first is, of course, the chemical function of enabling the cement to set, and to form certain combinations. The second, is that the water acts as a lubricant which enables the various constituents of the concrete to flux or settle down into their places when they are rammed or shaken.

I may say that the percentage of water required for chemical combination is probably not more than 8 or 10 per cent. of the weight of cement used, which is obviously an impossibly small quantity for practical purposes, since if insufficient water is used in gauging to produce proper lubrication, the concrete will never flux properly into position, and will be weak and porous.

I wish to congratulate the Committee on what I may call their common-sense recommendations, and I quite agree with them in No. 1, that it is inadvisable to lay down any definite rule as to the percentage of water that should be used. That, perhaps I may be again allowed to say, is entirely common sense, because the conditions must vary in every instance, first of all, with the cement used, and, secondly, with the kind of aggregate used ; climatic considerations must also be taken into consideration.

In recommendation No. 3 it is stated that the concrete should be sufficiently wet to pass between the reinforcing bars, and to thoroughly surround every portion of the steel. Well, of course, that again is

obvious. Some time ago I was professionally engaged in a case in which some reinforced concrete piles failed, owing to the concrete being gauged too dry in making them. The pile, when it was driven, fractured and split, and the contractor, as usual, laid the blame on the cement. Examination of these piles and of the reinforcement showed that the concrete was made so dry that only about a quarter, or perhaps a third, of its surface was in contact with the reinforcement, thereby altogether nullifying the junction of the latter.

I was greatly interested with Mr. Wells's remarks about the use of broken Fletton bricks in concrete, and the failure resulting therefrom, but I really do not quite understand—without wishing, of course, to doubt his authority as to the composition of the bricks —how there could be 17 per cent. of sulphuric anhydride in them ; 17 per cent. of sulphuric anhydride would correspond to somewhere about 25 per cent. or more—30 per cent. perhaps—of calcium sulphate.

MR. WELLS :—22½ per cent. of calcium sulphate.

MR. BUTLER :—Well, I cannot conceive any brick standing for even a month exposed to wet with all that amount of calcium sulphate in it. We all know that calcium sulphate, or plaster of Paris, is absolutely non-hydraulic ; it goes to pieces in water, and I cannot conceive any brick containing that amount of calcium sulphate. If it did contain that amount, I can quite understand Mr. Wells's remarks as to the concrete blowing, because it is a well-known fact that if there is much calcium sulphate either in the aggregate or in the cement, it will cause blowing. I myself have more than once met with cases in which old bricks with plaster adhering have been used as aggregate, and it has caused disintegration of the concrete. I shall therefore be very glad to receive from Mr. Wells a copy of the Report.

MR. WELLS :—I will send it round, and I will ask Mr. Davis to send you photographs of the brick showing the state, and also results in the concrete. I will ask Mr. Perkins also to do the same.

MR. BUTLER :—Thank you.

MR. P. M. FRASER, A.R.I.B.A., M.C.I. :—Mr. Chairman and gentlemen, I have very great pleasure in adding my thanks to those which have gone before to Mr. Vawdrey as representing the Committee. I have not much to say with regard to standardisation of drawings, except that the two scales which he rather deprecates, the $\frac{1}{4}$-in. and the 1-in., I agree with a previous speaker are the two most useful scales that could possibly be employed. I am speaking, of course, as an architect, and Mr. Vawdrey did not make it quite clear to what type of drawing he was referring. There are two real types of drawing in connection with reinforced concrete building. The first is the architectural drawing and the second is the reinforced concrete drawing, and to a certain extent they are separate. I use the $\frac{1}{4}$-in. scale always for plans of buildings covering up to 25,000 ft. super. It is said that drawings of that size are too large, but they can be cut in half or in quarter, and there is not the slightest objection to cut them up to any size you like. It is often a great convenience to have your drawings cut up ; and if you have any question to settle on any part of the building you can take a small portion of the drawing, which is easily handled, about 2 ft. square, to that particular part. You do not generally walk about the building with drawings under your arm.

With regard to the consistency of concrete, a subject in which I am very much interested, the last speaker mentioned piles which were mixed too dry. Well, I had a case two or three weeks ago of five piles which were wanted in a great hurry. In fact, I mentioned these particular piles at the last meeting here. They were mixed very dry. The contractor, when I approved of the consistency of the concrete, was quite aghast. He said, " It looks like the inside of a Stilton cheese, and I am sure it will fall to pieces." These piles were driven in twenty-six days. After making, they were driven with a 30-cwt. monkey with a 5-ft. drop ; and although the heads fractured rather, there was not the slightest appearance of fracture at any part of the pile except just under the head.

The word " plastic " used in this Report is rather

a misnomer. I think concrete cannot be plastic. Plastic means that which is capable of being modelled or moulded. It is quite opposed to something capable of being cast, and I think on strict grounds in a formal Report the word "plastic" should be superseded by some other word.

Also the word "ramming." Ramming presents, to my mind, the action of striking heavy blows with a heavy tool, and in reinforced concrete I think this is quite wrong. You cannot get that artificial strength which we all know concrete will obtain which has been consolidated during its setting. You cannot get that by ramming; you get disruption more than increased strength. The only ramming, so-called, which I should recognise consists of poking with an iron rod, and nothing in the shape of a heavy weight.

The suggestion "quivering like a jelly" is one which I always take exception to. A jelly does not quiver on account of fluidity; it quivers on account of its elasticity, and when it is in the mould it does not quiver at all, and cannot be made to quiver. The words "like a jelly" seem to be quite superfluous there. When you say, for instance, "after thorough working should quiver," you say quite enough there, I think.

As I have already indicated, I am very strongly in favour of a dry concrete. The Committee, although they do not actually uphold wet concrete, seem to imply that the wetter a concrete is, within certain limits, the better. I take the view that the dryer it is, within certain limits, the better. The moral of paragraphs 2, 4, and 5, with regard to the ordinary strengths of wet and dry concretes compared, is to use your concrete dry and get your ultimate strength as soon as you can, putting on one side the fact that wet concrete will never get the same eventual strength as a dry concrete; and where the reinforcement is particularly complicated, you do not get over that complication by using a wet concrete, whereby a sort of mud gets underneath the bars and a mass of large stones gets on top of the rods. One wants to use a fine concrete at these points, bringing it down to $\frac{1}{4}$-in. stuff, or $\frac{1}{2}$-in. at the outside, and supervise at those points as much as one can and see that they are

properly punned. One of the correspondents inquired whether a greater amount of water is required for a quick or slow-setting cement. I have not had any experience of that, and I shall be very glad if any gentleman here will give us any information on that point.

A suggestion is put forward that sand and cement should be mixed dry and then wet, and then mixed with the aggregate later on. Anybody who has seen that process actually carried out, I think, will bar it once and for all. It is a most painful thing to watch, and it costs, I suppose, five shillings a yard more for labour ; and I am sure the result, except in perhaps one or two very elaborate mixing-machines, must be very bad.

There are a few rough-and-ready methods of telling whether the consistency of concrete is right. If you load concrete into a barrow, by the time it is wheeled into its place, it should not have taken a horizontal surface. You should be able to take a shovelful of concrete from the bank and hold it at a slight angle, and it should show no signs of the cement dripping away. Also you should be able to make a hole in the concrete in the barrow which no amount of ordinary vibration should ever cause to fill in.

In conclusion, I should just like to read an extract from one of our leading technical journals, which I think may amuse, if it does not instruct you. It is an editorial which says : " A correspondent thinks the following extract from a specification lends itself to innocent mirth :—

" ' The concrete to be carefully packed over and between the bars and well rammed until the mass quivers like a piece of liver.' " (Laughter.)

The Editor goes on to say that this suggests a simple rhyme which can be committed to memory by a foreman, clerk of works, or others interested in the question of consistency of concrete, namely :—

" Let the concrete be carefully packed
Between and right over the bars,
Well rammed and judiciously thwacked ;
Till, under the consequent jars,
It shall sheenily shudder and shiver
Like a lump of resilient liver."

(Renewed laughter.)

Mr. Thomas Potter, M.C.I. :—I have jotted down a few notes from my own experience. Where the aggregate is of one kind and consistency, there is obviously no difficulty in ascertaining the amount of water required, assuming that the aggregate is not some dry and some wet. In an ordinary way there are many difficulties to contend with. The aggregate may be of a porous nature and absorb a good deal of water, or it may be gravel, which would practically absorb none. Then, a small aggregate requires more water than a larger one. It may have to be washed, and would then require a less amount of water than if dry. It depends, too, upon the purpose the concrete is for.

For monolithic walls it cannot be rammed or compressed between the forms to any extent, or the form boards may be pushed out of place. For floors it can be beaten or compressed. As a result, more water is required for concrete for walls than for floors.

If too much water is used, the excess may carry away with it some of the cement, and is in evidence as the water, not necessary for hydration, comes through the joints of the form boards of floors and walls. The water parted with in this way should be quite clear.

For floor purposes, if too much water is used, it comes rapidly to the surface when beaten or compressed, and cement adheres to the surface of the beater. Violent beating of the concrete, except when it is in large mass form, causes the water and cement to quickly come to the surface, which is avoided if the impact is of a gentle character and quickly performed. An intelligent foreman will soon ascertain how much water is essential for the purpose it is required for. If too little is used, the finer portions of the aggregate do not slide into place readily, and the concrete is not homogeneous ; if too much is used the water that escapes will take with it some of the cement.

The amount of water necessary is one of those things very difficult to standardise for general practice. I prefer the personal equation in determining the amount, assuming a capable man directs the work.

When the aggregate has to be washed previous to and at the time of use, and is of a non-absorbent character, but containing mud or clay, as gravel from sluggish streams, or pits where it contains clay, a very small amount of water is necessary for mixing purposes.

Mr. E. FIANDER ETCHELLS, F.Phys.Soc., M.C.I. :—Mr. Chairman and gentlemen, with regard to the first Report, I should like to supplement a few of its requirements. I would not make them obligatory, but they are merely one or two hints or suggestions by which the drawings, when standardised, would be more quickly and more readily intelligible to those who had to interpret them. First, it would be desirable that the prints or drawings should be indelible black-line photo prints on white linen. The white linen will enable any alterations or additions to be readily shown, and that cannot be done with the blue prints. Another objection to the blue prints is the danger to one's eyesight in examining them day after day and hour after hour in a dark, foggy place like London so often is. Mr. Serraillier made a suggestion with regard to hatching on blue prints, and I also would like to give another which, although old, may nevertheless be new to a few of the members. It is that with a blue print, which is difficult to trace, it can be laid over a thick sheet of plate-glass with the ordinary electric light behind it, and it will then show up very plainly and can be traced readily. I would also suggest that any tracings which should be made should also be made on the unglazed side of the linen, the reason being again that any pencil-notes can be readily made, and that is difficult on the glazed side. Then, again, if the scale on which the drawings were made were drawn on as well as being described in words it would be a double advantage ; you would have a greater freedom in selecting your scale. If the scale were drawn in two directions at right angles to each other, it would not matter so much how the print expanded or contracted during the process of reproduction. With the linen prints particularly they are not always true to scale, but with two scales, one perpendicular and one drawn horizontal, you can get a very fair idea of dimensions when all the measurements are not given.

It would also be desirable that the north point should always be indicated on all plans, and also all plans of the same building should have the north point leading in the same direction as far as practicable. Then you can lay one plan over another. Much time is lost and much annoyance caused in having to twist the plans of complex buildings round and round to find which way they are to go, and to compare one with another.

All sections should bear the title or reference, clearly indicating the position of the section plane and *the direction of the point of view*, etc. ; and also it would be desirable that all views should be projected from one another, as far as possible, and be placed in the geometrically correct planes. There is very little mistake ever made with regard to the plan of the front elevation, but the principles by which those have been deduced should be extended to the side elevations, and from that it follows that the left-hand elevation will be projected on to a plane at the right-hand side of the plan and vice versa. Some confusion is occasioned by those who have learned to draw before they have studied geometry, and who persist in placing the left elevation on to the left side. I express the hope that those who make the drawings will keep in mind the Universal and International Conventions of Geometry in this particular.

When details are not projected from one to another, or where they are not closely related, then there should be a greater space between the separate views, so that the eye can readily perceive to what part the details appertain.

Another desirable feature in reinforced concrete drawings would be that the proportion and nature of the concrete and the minimum crushing load at one month or at three months should be clearly indicated on the plans. We naturally expect to find it on the specification, but with the amount of specialisation which exists at present the specification and the plans seem to part company and fall into different hands, or we do not see them at the same time.

With regard to the second Report, I also object, as one of the previous speakers did, to the references to table delicacies in an engineering definition, and I would

eliminate that too homely simile. Under conclusion 2 of the Report it is said that the strength of concrete, apart from any reinforcement, increases as the amount of water used in mixing is decreased. I think the Committee were quite right in not building anything on that definition, because it is so obviously inaccurate. Suppose the amount of water be decreased to zero itself, that does not increase the strength of the concrete. The limitations of the definition are glaringly obvious.

With regard to Reply No. 6, a third correspondent says that usually about 22 per cent. of the total volume of cement and sand is taken for the amount of water. It seems strange why it should be 22. Why not 21? Why not 23? Apparently what is happening there is that the writer has an opinion that water to the extent of 15 per cent. of the volume of the cement and sand is required to enter into chemical combination therewith, and he has provided over and above that a surplus of about 50 per cent., which would bring it to about $22\frac{1}{2}$ per cent., or, in round figures, 22 per cent. But there is a danger; we speak of theoretical amounts. That is only part of the theory. The Secretary himself, and later on in the evening Mr. Butler, mentioned certain other factors which enter into the consideration of the question. Any complete theory takes into account every one of these. That is where the judgment comes in, inasmuch as judgment is the unconscious summing up of all the factors that enter into the case without our being consciously aware of the influence of any single factor.

With regard to No. 23, the correspondent wishes to get rid of the personal element, and he suggests a method of doing so. That procedure has been developed in physics generally where, instead of the adjective "big" or "little" or "large" or "fair" or "middling" or "ordinary," they have endeavoured to get definite figures. That suggestion might be followed up. But it is not very clearly expressed.

Then, again, correspondent 24 errs the other way. Instead of definiteness, he says "the consistency of thin cream." Well, the consistency of thin cream is very, very vague indeed, too vague for this Institute, I fear. (Laughter.)

I have tried to co-ordinate the views of all the correspondents and of the Committee. There seems generally an idea in the minds of each of them, a collective idea as to what the consistency should be, and the difference appears largely to be in the matter of words. Therefore I would suggest this for your consideration : *For reinforced concrete the amount of water to be added should be sufficient, but not more than sufficient, to produce a plastic mass which will quiver when shaken, and exude a small amount of water after tamping.* Now, it is quite possible that that definition will not suit a single person in this Institute, because it is an attempt to co-ordinate the views of most of them, if not all of them. (Laughter.)

THE CHAIRMAN (Mr. WENTWORTH-SHEILDS) :—If no other gentleman wishes to say anything, I will ask Mr. Vawdrey to reply. As the hour is late, I will only suggest one thing which perhaps he might have an opportunity of dealing with, and that is that this second sentence in this specification, which apparently has received the Committee's blessing, does not seem to me to tell you anything at all. It says that the quantity of water shall be such that the plastic mixture is capable of being rammed into all parts of the moulds and between the bars of the reinforcement. That rather reminds me of an old foreman to whom I propounded this question that we are discussing this evening, viz., What is the correct quantity of water to use in concrete? He replied in a very serious and thoughtful manner, "Well, sir, the great thing is not to put too little and not to put too much," and he seemed to think that had solved the matter. (Laughter.)

This question seems to me to be answered by the Committee in very much the same way, because one naturally asks in return how much water is required. Would it, for instance, be a wet mixture which is capable of being rammed into all parts of the mould, or would it be a dry mixture? Mr. Fraser would, I think, contend that his dry mixture was capable of being rammed into all parts of the mould, but Mr. Vawdrey and his Committee, I think, would deprecate that. It would be well to have a definition which

would settle this question a little more closely. (Applause.)

MR. R. W. VAWDREY :—I think perhaps, as the Chairman himself has made this very direct and forcible attack on the Committee, I had better answer his question first. I can only say that I think every member of the Committee would be inclined to agree with him. The attempt to answer the question as to how wet the concrete should be has, of course, failed. That I think we must admit. The suggestion contained in the second sentence which was submitted in the letter to the members of the Institute was, at any rate, intended by the Committee to indicate the lines on which we wanted a reply. The answer given by the Committee is more or less contained in the clauses 1 to 6 which appear afterwards. But I entirely agree, personally, with the Chairman that it is impossible to say how wet or how dry a mixture should be in words. In my opinion, as I think I mentioned just now, a percentage of water does not indicate the degree of wetness or dryness of the mixture, and, therefore, my own view is that some sort of scale of consistency should be evolved, if possible, by this Institute, which would make it possible to refer to a particular degree of consistency of the concrete.

With regard to the remarks which have been made, there are one or two points I should like to reply to. Mr. Serraillier, for instance, objected to a large lettering on the score of beauty and suggested stencils. I confess that even large lettering, which I admit is quite ugly, is not quite so bad as stencils. Of the two I prefer the lesser evil.

Mr. Bylander mentioned the question of the standardisation of drawings, particularly as applied in the United States. For some reason or other, which I never myself have been able to understand, standardisation does not seem to thrive in this country. I do not know why it is at all. If Mr. Bylander can, at any time, give me any information about that I should like to hear it.

MR. BYLANDER :—I think you are starting very well, Sir.

Mr. Vawdrey :—Personally, I am trying in a small way to standardise things, but it does not work somehow or another. The scales of one quarter and one inch which Mr. Bylander spoke of, I think are more or less covered, and preferably so, by the half and one-and-a-half-inch scales. The great advantage to my mind of the one-and-a-half-inch scale is that an ordinary foot rule, which every foreman or most navvies possess, will at once enable him to read the drawing. The eighth of an inch mark on the foot rule represents an inch. That is the great advantage, I think.

Then I entirely agree with Mr. Bylander about the importance of order lists, and the extent to which they will become important, and also with his remarks about having each drawing half the size of the larger one. That is, I think, very advantageous from many points of view, economical and otherwise.

Mr. Fraser asked what particular drawings the Committee were referring to. The answer is to the details of reinforced concrete, not general architectural or engineering drawings, but particularly those drawings which are prepared for the showing of reinforced concrete. I entirely agree with Mr. Fraser's remarks about the advantage of having a big plan cut up into details.

He objected to the word "plastic." The difficulty is to find a better one; in fact, I noticed Mr. Fraser himself merely suggested another word, without mentioning what. It is rather difficult to express.

I think that Mr. Fraser would disagree with most of us in saying that ramming cannot be done. I think it can be done on fairly dry concrete which Mr. Fraser himself would advocate. In fact, he himself later on said in difficult portions of the work he would use a very fine concrete, which should be thoroughly tamped. I take it in that case he meant it should be fairly dry, sufficiently dry, at any rate, to resist the operation of tamping or ramming. The Committee certainly did not imply the wetter the better. That was not the general feeling of the Committee. If that appears in any way in the Report, it is rather regrettable; the general feeling is that wetness is an evil, as I think I have remarked before, but that in some cases it may be a necessary one.

Then, again, I think most people would agree that in some circumstances the mortar—that is, the sand and the cement—can be mixed wet and be poured over the aggregate. Of course it is not advantageous in all cases, and sometimes would lead to disaster, but I have seen cases in which that has been done with excellent effect.

Mr. Etchells made remarks about the white versus blue prints. Well, everybody agrees that white prints are very much pleasanter to deal with, and are, I suppose, better for the eyes, and so forth. The only object that I ever heard or knew for using blue prints was that they were very cheap and speedy. Alterations can be made on blue prints. I think Mr. Etchells said there was great difficulty in doing that, but with white ink, which can easily be obtained, alterations can quite satisfactorily be made. But I entirely agree, assuming that cost is no object, that white prints are infinitely better.

Then I should be very glad if Mr. Etchells would explain, to me, at any rate—possibly most people know, but I certainly do not—why, when the universal practice, or almost the universal practice, is to use the unglazed side of tracing cloth, the manufacturers continue to prepare the glazed side on purpose for it to be used?

Mr. Etchells suggested that by drawing the scale on the drawing in two directions any difficulty as to the drawing being true to scale in all dimensions and in all directions was got over ; but of course the recommendation in the Report is that it should never be necessary to rely on scaling distances, that all dimensions should be given. (Hear, hear.)

Then Mr. Etchells accused the Committee of bringing table delicacies to the fore, but I would point out that the words "quivering like a liver" are not used in the Report. We just avoided that by the skin of our teeth. (Laughter.)

I entirely agree with Mr. Etchells as to the use of the word "theoretical." Nothing appears more absurd to me than the way in which theory is said often to conflict with practice. If so, the theory is either incomplete or incorrect or else the practice is wrong.

MR. ETCHELLS :—Might I just for a second supplement my remarks? I will not give the Hon. Secretary of the Committee anything to reply to again, but I hope we will each of us value our eyesight, which cannot be replaced at any cost, however high, above the slight difference in cost between blue and white prints. I have used white ink or common soda for making alterations on blue prints, but it is not so convenient as the black ink to be found on every desk, or the ever-ready blacklead pencil.

THE CHAIRMAN (Mr. WENTWORTH-SHEILDS): —Before making my final announcement, I would remind you that refreshments can be obtained at the Institute offices on the first floor of this building. I will conclude by telling you that the date of the next Ordinary General Meeting is February 8th, when a discussion will take place on the paper by Professor Beresford Pite on the "Æsthetic Treatment of Concrete," which was read during the Summer Meeting in June last. This meeting is therefore adjourned till February the 8th.

The meeting then terminated.

The following notes have been received from MR. E. G. WALKER as a contribution to the discussion :—

Clearness and completeness of detail in the drawings of any engineering or constructive work are undoubtedly potent factors for economy, and the cost of preparation of drawings forms usually a very considerable part of the standing charges of a job. In both these matters reinforced concrete forms no exception to the general rule, and therefore any rational method whereby drawings of reinforced concrete structures can be standardised without affecting appreciably their general legibility is worthy of detailed consideration. It is obviously impossible to lay down absolutely hard-and-fast rules to govern every particular in the preparation of drawings—the diverse nature of the objects to be delineated prevents that—but, at the same time, there is no reason why all drawings of reinforced concrete should not be prepared with a considerable degree of uniformity.

As we in this country have not the advantages (and disadvantages) of a decimal system of measures, our ordinary working scales naturally divide themselves into two classes. If we start with the full-size object and set it out to smaller dimensions on a system of continual bisection, we get successively 6 in., 3 in., $1\frac{1}{2}$ in., 3/4 in., 3/8 in., and 3/16 in. to a foot. On the other hand, starting with the inch as our unit, we get 1 in., 1/2 in., 1/4 in., 1/8 in., 1/16 in., and 1/32 in. to a foot. For large details we must use the first system, for an extension of the second system in the upward direction, giving scales of 2 in., 4 in., and 8 in. to a foot, is obviously inconvenient, as having no simple relation with the full-sized object. For small-scale work the universally adopted 1/4-in., 1/8-in., and 1/16-in. scales fit in so well with the graduations of the ordinary rule that there can be no question as to the superiority over the scales of 1/32nd, 1/64th, and 1/128th full size. It is only when dealing with the intermediate sizes which are included in the range between $1\frac{1}{2}$-in. and 1/4-in. scales that there can be much room for difference of opinion. On large-scale drawings we are measuring inches primarily; on small-scale drawings, feet. On the intermediate-scale drawings, such as are referred to in the Report as "elevations of beams, etc., and general detail drawings," the fact that such are detail drawings implies that the representation of inches is aimed at, although only as forming part of dimensions involving, perhaps, several feet. On such drawings, therefore, convenience in scaling the larger dimensions should give precedence to ease of picking out items involving, say, up to 20 or 30 in. It would thus appear that the scale to be used should be one on which, when the ordinary rule is applied, inches can be read off easily and to a fair degree of approximation, leaving the accurate measure of inches and fractions thereof to the large-scale details drawn to $1\frac{1}{2}$ in., 3 in. to a foot, or even half or full size in exceptional cases. This consideration points to the advisability of a more extended use of the 3/4-in. scale (on which 1/16 in. represents an inch). In reinforced concrete practice there is probably little scope for the employment of the 3/8-in. scale, for it is generally too

small for the purpose of intermediate detailing, whilst being too large for the general drawings for which the 1/4-in. and 1/8-in. scales amply suffice. Its field of usefulness is rather to be found in certain classes of structural and machinery drawings than as a standard for reinforced concrete work. But the 3/4-in. scale is on a different footing. In addition to the favourable argument already adduced above, it also possesses the advantage that it is half the $1\frac{1}{2}$-in. scale, and this is a great convenience in drawing, enabling as it does the general detail to be made up easily from the particular.

The Committee, whilst rejecting the 3/4-in. scale, give in their Report a very good practical reason for its adoption. In discussing the utility of the 1/2-in. scale they state (p. 321) "but 1/2-in. scale is too small to enable details of the reinforcements to be shown in any but a diagrammatic way." Later on, dealing with the 1-in. scale, they state, "but the 1-in. scale is often too large for detail drawings of long beams, and takes up much time in the drawing office." Surely, then, the solution of the difficulty is to be found by taking the middle course and using the 3/4-in. scale. By so doing we get a drawing which can be made to show as much detail as a 1-in. scale drawing, whilst reduced to a more convenient over all size. It can be prepared at less cost than the 1-in. drawing, and reinforcement does not have to be indicated diagrammatically, as the Committee complain is necessary on the 1/2-in. scale.

It appears, therefore, that the general recommendations of the Committee as regards scales need amendment only in the particular of substituting the 3/4-in. for the 1/2-in. scale "for elevations of beams, etc., and general detail drawings."

The Committee's recommendation anent the use of lines of varying thickness to indicate various classes of reinforcement, etc. (p. 322, "Indicating the Reinforcement"), appears to be rather unpractical. Different draughtsmen employ different thicknesses of line, and, indeed, variations of thickness are often to be found on the same drawing. As nowadays so much tracing work for the reproduction of drawings is done by non-technical tracers, to whom these fine

distinctions between classes of lines would not appeal, confusion is likely to result from the extended use of this convention. The substitution of the 3/4-in. scale for the 1/2-in. scale, to which the Committee propose to apply the convention, does away with the necessity of employing diagrammatic arrangements, and puts these details on the same footing as the larger scale details referred to in their next paragraph.

The abbreviations proposed for use on drawings appear generally to be suitable, and in most instances possess the recommendation that they have already been found convenient in practice. The following criticisms suggest themselves, however.

The letter "b," when written on drawings, is apt to get confused with the figure "6," and for this reason the letter "r," the initial letter of the word "rod," might be considered as a substitute for it. The importance of this point is minimised by the fact that succeeding symbols provide a method whereby the use of the symbol "b" is to a great extent eliminated.

It is probably more convenient to turn the symbol for a channel bar through a right angle, thus [.

The symbol □ having been already appropriated, it seems preferable to indicate square inch and cubic inch by sq. in. and cu. in. respectively, rather than by in^2 and in^3 between the indexes of which confusion can easily arise. Also for indicating the Imperial Standard Wire Gauge there seems to be no reason why the more usual abbreviation S.W.G. should be discarded.

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THE CONCRETE INSTITUTE

TWENTY-THIRD ORDINARY GENERAL MEETING

THURSDAY, FEBRUARY 8, 1912

THE TWENTY-THIRD ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held in the Lecture Hall at Denison House, 296, Vauxhall Bridge Road, London, S.W., on Thursday, February 8, 1912, at 8 p.m.

SIR HENRY TANNER, KT., C.B., I.S.O., F.R.I.B.A., F.S.I., etc. (President), in the Chair.

The following were elected members of the Institute :—

MR. EWART S. ANDREWS, B.Sc. (Eng., London), London.
MR. PERCY BOULNOIS, M.Inst.C.E., F.R.San.I., etc., London.
MR. WILLIAM E. J. FETT, Hull.
MR. JAMES A. MALCOLM, London.
MR. R. L. NICOL, Padstow, Cornwall.
MR. J. VAUGHAN STEWART, Lebu, Chile.
MR. GEORGE S. ROBERTS, London.
MR. DAVID DONALDSON, London.

THE SECRETARY (MR. H. KEMPTON DYSON) announced that MR. WILFRED LEVER, Ashton-under-Lyne, had been admitted as a Student of the Institute.

THE CHAIRMAN (Sir HENRY TANNER) :—We shall now have the great pleasure of listening to Pro-

fessor Beresford Pite again this evening, and as a preliminary he will read his paper again. He thought it would be an advantage to all those present and recall to them what he said on a former occasion, now rather a long time ago. (Applause.)

PROFESSOR BERESFORD PITE then read the paper which he submitted to the Seventeenth Ordinary

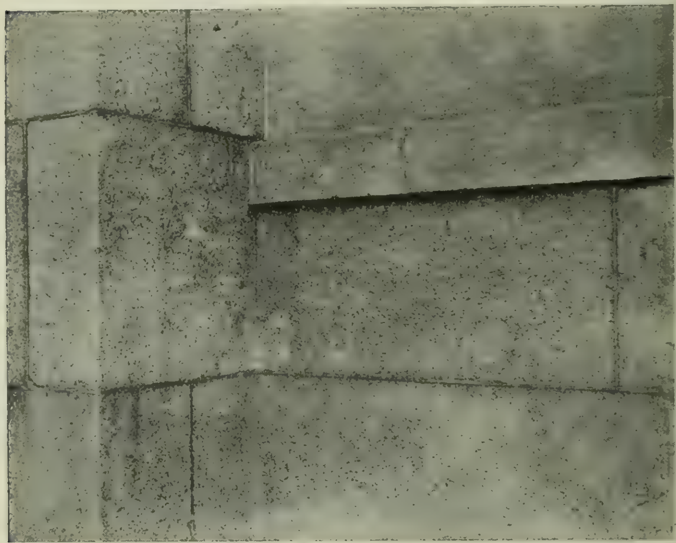


FIG. 1.—Part on Left built of Granite. New part on Right built of Concrete in imitation of Granite.

General Meeting of the Institute on Wednesday, June 7, 1911, on "The Æsthetic Treatment of Concrete," and which is printed in the TRANSACTIONS, Vol. III. pp. 239-51.

PROFESSOR PITE :—Now we will have a few photographs.

Fig. 1. A photograph of the texture of granite on the left ; an imitation texture of concrete on the right. It sets at defiance, of course, all attempts at other definition.

Fig. 2. A modern American building in reinforced concrete, an office building at Boston. It is an æsthetic treatment of reinforced concrete, without any doubt,

FIG. 2.—Office Building in Boston, U.S.A., built entirely of Concrete.

but under the homely and natural conditions of the laws of stonework æsthetic. The very graceful doorway, of a Greek type ; the treatment of the pilasters and the treatment of the architrave are Greek. In so far as they are Greek, they are imitations in marble

of a wooden parentage now translated back into a plastic reinforced concrete, in which, of course, the

FIG. 3.—Maison Félix Potin, Rue de Rennes, Paris. Mons. Auscher, Architect.

thickness of the wall and the size of pier do not matter a rap. I venture to describe my doctrine as commencing, not leaving it, here. Adaptation of the

recesses, of the mouldings, possibilities of projection, are open to us in reinforced concrete without losing the æsthetic values arrived at by proportions of decorative development and by traditional design. You can easily imagine, I hope, a compromise between the treatment of the front and the treatment of the side of this building. The treatment of the side is unabashed reinforced concrete plus rusticated joints, for which there is no possible excuse other than an architectural one. Let us take the architecture which is lavished on the

Fig. 4.—Block of Flats, Savona, Italy. Mons. Martinengo, Architect.

front and apply it thinly on the side, not being afraid of its thinness, recognising the fact that its thinness is its texture.

Fig. 3. A house in the rue de Rennes, Paris. The designer has been at great pains and suffered considerable mental excitement in the endeavour to persuade us that this is not stone. It is obvious that this is plaster. The whole of the free curves and the glorious bubble on the top mean the man has been in earnest in his attempt to teach us that this is simply not a stonework building. It is the struggle of these

building problems with artistic problems in reinforced concrete, but I should hesitate to call it æsthetic treatment. It does not justify itself as being a work of

FIG. 5.—Mons. François Hennebique's Villa at Bourg-la-Reine.

simple constructional perfection, which would, in the long run, justify itself without reference to any architectural attempt.

Fig. 4. A treatment at Savona, where the artist has

felt himself conditioned, very much on the lines which I have suggested, by the traditions of the horizontal cornices, and he has been able to exaggerate projections and recesses and even ornamental features. Treatment difficult to understand in stone is quite easy to realise in reinforced concrete, and, so far, it is on the right lines. It seems to lack in sense of refinement and restraint, because the artist has been struggling to express with freedom that the projections which would not weather in stone will weather in

FIG. 6.—Dwelling House, 40, Rue Boileau, Passy, Paris. Mons. Richard, Architect.

reinforced concrete. There is an excitability in the use of the detail which is very troublesome to the eye indeed, but in so far that the building proceeds upon a developed exaggeration in concrete of traditional achievements in Renaissance palace architecture it is interesting. I venture to suggest humbly, in the absence of the author, that it just fails in the æsthetic quality of the architect's mind. That, of course, is a personal criticism which one must make with every apology.

Fig. 5. M. Hennebique's own residence, designed

obviously as a *tour de force* in the construction of projections. I do not want to make any suggestions on this design æsthetically; I leave that to the treasured private judgment of every one. But I would point out that this does express—by way of advertisement—the possibilities of projection. The interesting flat cantilever and great cantilever beyond are directly an expression of reinforced concrete construction, because we could not do it in stonework or brickwork. We feel at once this is a novel material in

FIG. 7.—Meeting Hall and Market Hall at Longage.

which such projections are possible. The enormous soffit of the balcony, the sudden curve of the tower, the entire want of relation in the proportion of the openings to the piers and the weights above them—all are manifestly concerned with functional design. An arch without a buttress; brackets without much appearance of thickness or strength or checking down. This is interesting. It is important, but it is not æsthetic treatment.

Fig. 6. A villa at Passy, near Paris, where the architect has manifestly thrown away normal architectural features, and dispensed with traditional design

and Italian detail or with any would-be æsthetic style. He dispenses with arches and uses a pointed lintel, uses it only as a decoration to a panel. The window lintel being manifestly very thin, the supporting lines are obviously the constructional lines of a frame building; they are not the lines of a building built up on horizontal courses. This cantilever treatment with the large opening behind directly and forcibly expresses the lines of stress and design in that angle of the building, and there is a feeling of intense pressure

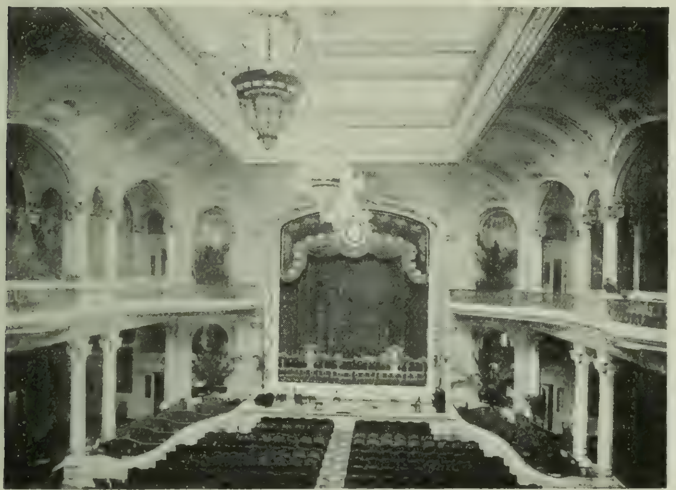


FIG. 8.—Casino of Beausoleil at Monte Carlo. Mons. Niermans, Architect.

and strain about these piers which the emphasis of the angles enables them to fulfil, just as one has no doubt as to the strength of a stanchion if you see it built up of sufficient plates and rivets. One's doubt is as to its being too strong, not as to its being strong enough.

Fig. 7. The Market Hall at Longage is interesting because of the barrenness in the reinforced concrete parts and the employment of brick as a filling in the market hall up above, and a certain felt liberty of design in a quite suitable place, that is, round the

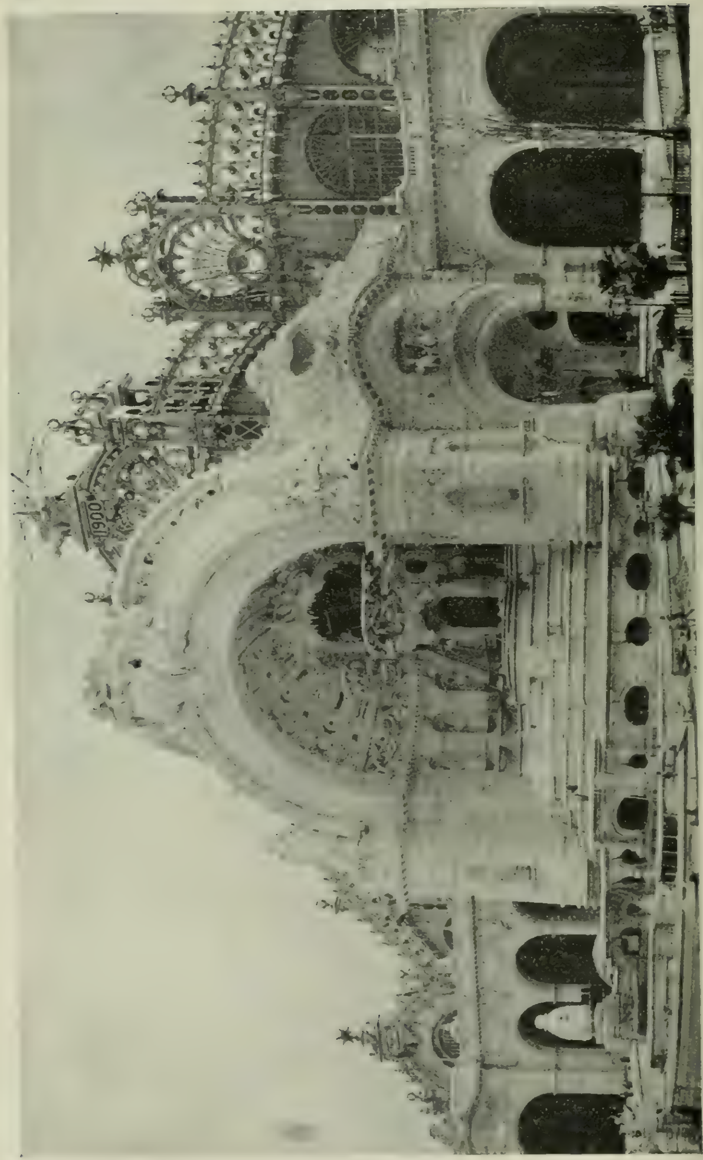


FIG. 9.—Chateau d'Eau, Paris Exhibition of 1900.

clock. But the reinforced concrete tells its story quite directly in all this structure, and there is no attempt in the juxtaposition of parts to group them architecturally. There is no tradition of architectural proportion, but the design is left to work out its own salvation. A man must be content to say, " Here is a Philistinism ; I am a Philistine, and I do not care a hang about your artistic fancies ; I am not out to please, I am out to do business." This may represent a certain aspect of life, but it is an aspect which denies life half its charm and beauty and fails to satisfy. It is satisfactory constructionally, but standing incessantly in the middle of your dear old home town you would loathe it, turn your back on it, and would be cursing the man who, with all his practicability and soundness of mind, has bestowed an eyesore upon your home.

Fig. 8. The scene changes to Monte Carlo, the interior of the Casino. We cannot describe this in any other way but as an attempt at æsthetic treatment. The curved treatment of the bracketing of the balcony is very easily achieved, but notice the shocking tendency to recklessness in ornamental forms owing to the great freedom with which the material lends itself to plastic modelling.

Fig. 9. A well-known example of riotous and rollicking ornamental effect is the Château d'Eau of the Paris Exhibition of 1900. The whole of these massive ornaments, one realises, are so much wedding-cake ornament in plaster on a large scale. I venture to say that here we welcome this *tour de force*. It is a triumph, but it passes under the category of temporary buildings, and, of course, does not affect us permanently. We should be sick if we had to live with it. This was erected for a purpose which was to be shortly concluded and to disappear, but one notices the extraordinary freedom and power with which the French draughtsmen and designers take hold of the possibility of a material and give expression to it. The arch is admirably employed there, and it makes the ordinary arch treatment which would be possible in brick or stone to look very tame. These enormous æsthetic treatments just a little over-do themselves for any permanent design. One would get sick of them. But they are highly suggestive. There is a

vast amount of matter here for the designer and the draughtsman. There is possibility. Obviously there is some ground between the Halle of Longage and the Château d'Eau of the Paris Exhibition.

Fig. 10. Torpedo-float in the harbour at Hyères. I understand it is, for the purpose of torpedo practice, floated out and then sunk, loaded apparently inside to a water-line at the sill. It interests me because of the Egyptian character of the outline, the sloping wall, the curved gorge, which are the features originally created by the reed and mud architecture of the Nile Valley,

FIG. 10.—Torpedo Launching Station in Hyères Roadstead, near Toulon, Var : View Afloat. Mons. de Perinelle, Engineer.

which became sacred through an age-long history and were imitated in granite, the most opposite of materials. The designer, whether consciously or not, has been led into the same form. Everything that is massive, everything that is solid too, originally was everything that was thin, and thin and empty, as it is, of course, appears this slight reinforced concrete structure.

Fig. 11. The end elevation. About its normal level at the water-line it is in a practising position for discharging torpedoes from the openings above and below.

Fig. 12. Bridge at St. Claude. It is in a picturesque position, and I have no hesitation in suggest-

FIG. 11.—Torpedo Launching Station for Hyères Roadstead, near Toulon : View in Dry Dock before admitting Water.

FIG. 12.—Bridge over the Bienne at Saint-Claude, Jura. Mons. Blazin, Engineer.

ing that it is a beautiful object, having the qualities of the material employed in a position where the mind is overwhelmed by natural scenery, with great restraint. The chief cantilever here thoroughly expresses itself. One does not feel that you are looking at an arch structure imitated in thin material. You feel at once that you are walking along a bracket, I was going to say a greasy-pole—(laughter)—till you come to the opposite one and are landed in safety on the other side of the valley. It is obviously a cantilever of concrete

FIG. 13.—Goods Station, Newcastle-on-Tyne, for North Eastern Railway Company. William Bell, F.R.I.B.A., Architect.

construction ; the overhanging footpath adds to the expressiveness, and the whole as an æsthetic value of the prime unconscious sort. It is not—and this is the point— an æsthetic treatment ; there is a difference.

Fig. 13. The only English example is the great goods shed at Newcastle-on-Tyne, where ferro-concrete beams have been used in practically the numbers we should employ of wooden beams with the same result of picturesqueness. This effect lies in the direct serviceableness of every member, nothing being superfluous and nothing simply decorative. Now,

success probably lies just in the perfecting of our architectural taste, until we are able to take something which has the seeds of æsthetic success and treat it with architectural knowledge and architectural refinement and with architectural decoration. (Applause.)

DISCUSSION.

MR. A. ALBAN H. SCOTT, M.S.A., M.C.I. :—I do not think on this occasion we should propose a vote of thanks to Professor Beresford Pite for his paper, as this was done at the meeting at which it was read, but I would propose a vote of thanks to him for his attendance here this evening to give us the chance of further discussion ; and, further than that, I might thank him for his most excellent lecture on architecture as a whole, apart from the æsthetic treatment of reinforced concrete.

At the previous meeting I referred to the question of the treatment by engineers of reinforced concrete from an architectural point of view, and although I was somewhat severely criticised, my opinion has been recently confirmed by the statement from a reinforced concrete engineer, who stated that he designed reinforced concrete beams, slabs, and constructional work, and that the lavatory arrangements and heating and such like could be left to the architect. That statement surely shows that engineers do not understand what architectural treatment means, nor the duties of an architect, and consequently the æsthetic treatment of concrete.

I would still advocate that for the present moment we give up all idea of applying ornament to any reinforced concrete work on any large scale, because I feel that if any attempt to apply ornament at the present moment is made we shall get most disastrous results ; and I think it is also Professor Beresford Pite's feeling that we should gradually grow up to something, and not attempt in any way to jump to any definite conclusion as to the proper treatment at the present moment.

With this comparatively new material there are other problems which arise and which considerably alter the architectural treatment.

It is possible, and in some cases absolutely necessary, to get very large surfaces on the underside of the reinforced concrete floors without any beams whatever, and the only relief to the ceiling is the fan-shaped form of the column top ; and it seems to me that with the columns spreading out into a fan shape excellent opportunities occur here for getting good and proper treatment, and opens up quite a new field for treatment.

I asked an engineer this evening if he thought it was possible to get successful façade treatment in reinforced concrete, and he at once said " Most decidedly." It turns out that it is treatment of plaster jointed up to imitate stone. I think that is a thing which we must avoid, and that is one of the reasons why I advocate no ornamental work for concrete ; leave it exactly as it comes from the centering and only take off the large excrescences, and leave the work as if it is hand work as opposed to machine work.

Now, I would go farther than that, and I would not have the concrete work faced up absolutely to a dead line.

Speaking of M. Hennebique's house, I think Professor Beresford Pite was rather severe on that, because he is aware that the building was put up purely with a view of showing what could be done from a constructional point of view.

I am exceedingly glad that Professor Beresford Pite has brought out the point about the creation of rusticated joints by sinking moulding fillets and his suggestion that it need not be even proposed. I would suggest that it should be very strongly opposed. It is coming more into use every day, both with plaster and also with reinforced concrete.

Some people have an idea that concrete is an essentially coarse material, and a material which requires coarse treatment, but I do not agree. I should do the same with concrete as I should with any other cast material, and I should not attempt to trim off every little point that happens to come along.

Would Professor Beresford Pite consider that it is a legitimate thing to construct the vaulting of a church with reinforced concrete, and apply superficial treatment such as mosaic, etc.?

I propose a hearty vote of thanks to Professor Pite for coming here this evening, and especially for the slides, which were exceedingly interesting ; and I am sure the members of the Concrete Institute will greatly benefit by the paper.

Mr. ARTHUR T. BOLTON, F.R.I.B.A. :—Mr. President and Gentlemen, it is very pleasant to me to come here this evening and listen to the paper which Professor Beresford Pite has just read to us. I have had the advantage, in addition, of previously reading the paper, and I should like very heartily to congratulate him on his clever treatment of an exceedingly difficult subject. The whole idea of how we are to deal with a new material is a matter which will involve a vast amount of thought, and the way must necessarily be very obscure at first. I think that probably some of those who are present would like to know of a little book on the principles of architectural design which is considered by many to be the best analysis of that very difficult subject. I refer to a little book, " Design in Architecture," by E. L. Garbett. It is in Weale's Series and cost about 1s. 6d. It was written about the time of the Gothic revival, and contains doubtless a good many views and statements that would seem absurd nowadays, but the main lines of it are remarkably good. (Hear, hear.) There is a very curious prophecy in that book which the last slide shown to-night seems to show has actually been realised. After taking his analysis right through, very much as Professor Pite has done, Greek, Roman, Gothic, and Renaissance architecture, the author sums up the whole matter by saying that in Greece we had the architecture of the post and lintel, and in Rome that of the arch, and that now there was no other constructive principle except that of the truss. It certainly seemed rather difficult to see in what way the truss could be brought into an architectural scheme, except in the form of roofs, which is obviously not the author's meaning. When, however, you visit a building like the Vere Street Post Office (which I had the advantage of going over with Mr. King, who constructed it) you find there trussed walls employed on a large scale. If I am correct in my recollection there are within the area of the plan of this building, which is of con-

siderable size, four pillars, on to which the weight is conveyed by trusses, probably in depth equal to nearly the height of this room. The windows of the building form in reality the openings in or interspaces of the truss. It is therefore a remarkable thing, you will agree, that Mr. Garbett in his analysis should have arrived at that conclusion and that we should already be in possession of a material which enables us to embody the principle of tension as exemplified in the truss.

It is a question whether this reinforced concrete was known to the Romans or not. I suggest to our engineering friends here to-night to consider the roofing of the cold-water bath of the Baths of Caracalla at Rome. This is a gigantic hall, 170 feet long, with a span of about 80 feet, and ancient writers tell us that its flat ceiling was one of the marvels of Rome. The ceiling, besides being flat, had in it three or four large central openings for lantern lights. How did the Romans construct a concrete ceiling on that gigantic scale, flat, and with these openings in it?

Professor Lanciani, who has devoted a lifetime to the study of the antiquities of Rome, in a little book called "Walks about Rome," or by some similar title, mentions that when the cold-water bath was explored great quantities of T-irons were removed. The plan of Caracalla's Baths is in every text-book on architecture, and our engineering friends here might see what they could do with that problem, and consider how with the aid of T-irons and concrete they would re-construct this wonderful feat of the Romans.

There is not the slightest doubt that Roman construction was extraordinarily advanced; we know practically little or nothing about it, but any one who wanders about Palatine Hill or the extensive grounds of Hadrian's Villa at Tivoli—and I might remind you that from the remains of Hadrian's Villa the thickness of the walls under the London Building Act was deduced—will come to the conclusion that the Romans had very little to learn on such subjects as brickwork and concrete. Moreover, we know that the roof of the Pantheon Portico, down to the time of the Barberini Popes, had some extraordinary trusses constructed of flat plates of bronze. There is a sketch

by Raphael of this metal framing, but unfortunately the bronze was melted up to form that monstrous Baldachino in St. Peter's at Rome.

The Romans in using concrete reinforced it with those splendid bricks, or quarry tiles, as we should call them, which they habitually used. These bricks were either 2 ft. or 1 ft. square, and $1\frac{1}{2}$ in. or 2 in. thick, and by their use they counteracted the shrinkage and other deficiencies of mass concrete, and also formed temporary or permanent casings and centerings which enabled them to press on with the work.

Of course we have by direct descent from the Roman times one text-book of architecture, but only, it is now recognised, one of a quite second-rate order, that is to say, the book of Vitruvius, a provincial architect and Imperial military engineer, who copied out, I imagine, from a standard War Office specification various building data of the period, and added thereto some ill-understood fragments from older Greek works on architecture.

That there was some standard specification used by the Roman Army I hold to be true, because in every part of the world, wherever you go, you find the Roman methods are remarkably uniform. The secret of the Roman concrete is a thing which to me is absolutely mysterious. I am very familiar with the great Roman fortress, a mile and a half from Sandwich, known as Richborough Castle. This enclosure, covering several acres, is still surrounded by a great Roman wall, one of the best preserved outside of Italy, and it was in this fortress that the Romans packed up on their departure from this country. The walls there are about 30 ft. high and 10 ft. thick, and of great length, but when the railways were being constructed the barbarians destroyed that which faced towards the sea in order to use the material for the purpose of the railway. They began to destroy the return wall to this sea front by excavating a great cavity at the base of the wall. It is more than high enough to walk into and it extends 8 ft. 6 in. in depth, and so leaves only 18 in. of walling beyond. The span of that opening is about 50 ft., therefore you have a concrete girder say 20 ft. in depth and 50 ft. span and 8 ft. 6 in. in thickness without the

slightest sign of a crack. It has stood since the time, say fifty or sixty years ago, when the cutting was made. In itself that is sufficiently wonderful, but suppose you go inside the wall and consider what it is constructed of. So far as one can see it is constructed of nothing but the materials on the spot. There you see the gravel from the beach, flints from the chalk, and the rough class of half stone, any kind of inferior Kentish rag, which could be obtained near the spot, while the mortar binding these miscellaneous aggregates together appears to be made with the ordinary chalk or stone lime.

What we want to know, therefore, is what did the Romans mix with that mortar which transformed it into a material as hard as our Portland cement? because inside this enormous wall, 10 ft. thick, the setting and consequent hardness of the concrete is just as good as it is on the outside. That is, of course, contrary to all experience with ordinary lime mortars.

When the Romans left this country something or other which had been mixed in concrete and mortar or some method of preparation was no longer used, and the Normans attempting to do buildings of the Roman character made a fearful mess of it. Most of their central towers collapsed, owing to the mortar being bad, as it became like sand, and the piers collapsed in consequence. Whether the Romans carried about with their armies puzzolana, or volcanic ash, or something equivalent to that in its effects, I do not know, but it is a subject I think exceedingly worth investigation by chemists and by societies like this Concrete Institute. To raise the level of the lime mortars, concretes, and plasters in common use would confer a great benefit on the building trade of this country, particularly in the country districts.

Turning now to another aspect of the question, the finish of walls in reinforced concrete, I happened to look in the "Engineering Supplement" of the *Times* this week, and I saw there a paragraph about mica having been used in facing certain reinforced concrete telegraph poles with good effect. Perhaps in granite, and in materials like mica, we should find a means of lightening up the surface of the concrete.

Any one who has tried, for instance, a rough cast of granite and Portland cement will know how very much better is the effect which can be obtained—thanks to the nature of the granite, and particularly from the pink Leicestershire granite—than is available from the ordinary gravels or sands. There are also, perhaps, considerable possibilities arising from the use of acids in removing the excess of cement over certain portions of the concrete surface, and in that way varying its terrible monotony.

I notice that the Professor, in his lecture, has omitted the Byzantine period. I think that is, in a way, rather a pity, because it was in Byzantine times that Roman architecture found itself. Byzantine buildings are practically Roman constructions released from bondage of the Greek orders. Probably you are all familiar with the inside of Westminster Cathedral, a very notable and magnificent piece of work, where we seemed to have realised for us on a grand scale something of the feeling of a genuine brick and concrete architecture.

Basing oneself on the Byzantine practice alone, I am afraid I cannot agree with the Professor as to there being any objection to their systematic finish by plastering, marble lining, mosaics, or otherwise, of both interiors and exteriors. The practice is of the most extraordinary antiquity, and as the question of shams has been raised, it is worth a few minutes' consideration. It was rather startling to me when I first spent some months in Italy to see at Pompeii, in the houses there, some of those remarkable marbled dadoes, in paint, that used to rejoice the hearts of the last generation. As an antique custom, however, this is nothing. We know now that the Cretans three thousand years ago, or perhaps more than that, did exactly the same thing. This practice of imitating materials, according to students of the earliest origins of mankind, began at once, and is therefore a trait which is so persistent that we are evidently in the presence of something instinctive, which requires accordingly a good deal of thought and reflection before it can be absolutely condemned.

There is not the slightest doubt that, starting as they did with the ordinary mud house, finished over

to one surface, the first builders, as soon as they first began to build in stone, looked upon its inevitable joints as a defect, and that it thus became an object with them to obtain enormous stones, monoliths as far as possible.

We are, in fact, told of such stones in the building of the Temple at Jerusalem, and we can see them in the base of the Temple of the Sun at Baalbec, the idea being to get walls which contained as few joints as possible. The system of jointing has been developed now, and it is a thing in which we take pleasure. On the idea of obtaining a surface, I do not think there is really anything against it that is worth considering from the point of view of a sham, because, after all, what we have to arrive at in architecture is, in some way or other, an effect of beauty, which, as we know, "doth of itself content the eyes of men without an orator."

We are, of course, getting on difficult ground; it is, perhaps, like truth in ordinary everyday life. I was once in a railway carriage where there were several commercial travellers, and they were discussing this very subject. One of these men closed the discussion by saying, with evident reluctance, that he was quite certain that a perfectly straightforward man would always make enemies. We know that the practice of speaking the truth is just as awkward in ordinary private life as it is in architecture and everything else. Certain diplomatic fictions, white lies, and other arrangements are used because otherwise, I suppose, society would fall to pieces. So it is in architecture. It makes one rather tired to hear people talking about the alleged sham dome of St. Paul's. That sort of talk is entirely beside the mark. There was no obligation on Sir Christopher Wren to show us the brick cone inside which carries that enormous stone lantern. I cannot see that it was necessary for him to force that on our attention, any more than it is anybody's duty to exhibit a bony framework, or any other constructive fact of a similarly ungainly character. You are not expected to believe that the great steeple—say, 90 ft. high—on the dome of St. Paul's is actually carried by the leaded dome which you see. That would be an unnecessary assumption on your part.

The beautiful effect of St. Paul's is justified on any sound system of architectural æsthetics for all time. I would not weary you with that except that it seems to me to bear on this point of the æsthetic treatment of these concrete structures, because I do not think it by any means follows that, when you have constructed these reinforced concrete buildings in some unusual way, you are absolutely compelled to force the fact upon everybody that you have done so. It is not the least bit interesting to us to see that house of M. Hennebique carried out in that extraordinary way. I think most of us would much rather he had brought out his projections, like the old Georgian bay windows, with simple flat soffits, and left us to find out how it was done. It is not necessary to draw anybody's attention to the way you do the thing, so long as it is not shocking in itself.

I fancy the real truth in this question of shams may lie in the intention, the mean motive, where it exists, causing the repulsion of feeling. It is quite certain that movements like Cistercianism and Puritanism have powerfully affected the development of architecture, but the reaction and the transformation following shows the partial rather than the universal truth.

There is no doubt that reinforced concrete is, in a way, a new material. I think it is different to the craze that there was in 1851 for iron and glass, and the idea that the Crystal Palace inaugurated a new era in buildings. That was all nonsense and came to nothing, but in reinforced concrete we have something which claims out of two materials to make a new one. Tredgold, in his work on carpentry, very properly condemns the idea that timber structures should be made up of timber and iron, because, as he says, the one material may fail to come to the aid of the other at the critical moment, and that therefore the union of the two materials is not necessarily stronger than either of the two, on the principle of the weakest link in the chain. As I understand, however, the theory, reinforced concrete, and the practice of it, so far as it has gone, it does claim that out of concrete and steel it makes a new material, having qualities which are something more than that which the mere joint use of the two might imply. There is, further, the aspect of per-

manency about reinforced concrete which has not been given hitherto by any other steel or iron building material. The exact way in which reinforced concrete is going to be used, and how eventually it is going to develop, is a question that not one, two, or three generations are likely to solve, so far as the architectural truth of treatment is now concerned.

May I say with how much pleasure I have listened to the paper, and now support the vote of thanks to the reader.

THE CHAIRMAN (Sir HENRY TANNER) :—Perhaps an engineer will give us his views now on the subject.

MR. E. P. WELLS, J.P., M.C.I. :—I must object that concrete *per se* is beautiful, and I am of the opinion that if we want to produce anything that is fit to look at, there must be some kind of external treatment to produce a good effect. All kinds of means have been attempted by plastering, imitation stonework, etc. Now and again one sees a building in concrete, especially if it is in the country, that looks particularly well ; if it is in town where it gets the usual London smoke, it then in a very short time has the appearance of nothing but dirty stucco.

Concrete can be made to look well if, when constructed, a surface layer, as you may call it, of mortar about $1\frac{1}{2}$ in. or 2 in. in thickness is worked into it. That applies not only to the surface of the concrete itself, that is, for the plain flat surface, but also to any projections you may have and any mouldings you may put on. And if that is done, even if no lines are shown to represent joints, it will then give a very respectable appearance. If the facing is made with the oolites or limestones it will in a very short time weather and become nearly white, and will present almost the appearance of Portland stone ; this takes about two or three years. It is also easy to tool, and at a very low expense a very decent appearance can be given to a concrete surface *per se*, without any plaster work of any description being added to it.

At the present time, as references have been made to silos, there is no doubt about it that in buildings of this description, if you put them up purely as a concrete structure, without any relief, you may well stick people's backs up at the want of architectural

beauty, but taking the size of such a building and its height, with careful treatment, with a few projections, and with pilasters, it can be made to look particularly well. As far as I can judge, and from my experience, the thing is not to have too many vertical lines. You want to get a series of breaks in the silo, and then you will get a good appearance. But if you keep vertical lines from the base right up to the top, it then becomes intensely ugly.

There is no reason why, when one gets into large structures outside of buildings, especially in bridge work and where you have large arches, it should not be jointed in the usual method so as to represent a stone face, because if you take a plain arch, without any relief of any description, you cannot say that it is beautiful unless you are some distance away from it. If there is a fog on, then the illusion is all right, but otherwise it is not beautiful. Still, as I say, it is possible to do it. There is no reason at all why, in the treatment of concrete, we should not adopt the usual architectural methods. It is an artificial stone, the same as you may say a brick building is artificial. Where natural stones cannot be obtained, as we know in some parts of the world—especially in America it is a most difficult thing to get building materials—why should you simply be confined to a surface to let the world know it is concrete pure and simple? There is no reason why it should not be moulded and simply adapted and treated in a proper manner so that it is pleasing to the eye. Every time I come into this room I am offended by the spacing of the dentils on account of the irregularity in the placing of the beams. It is the same all round. You may take this room as an example of concrete, and all absolutely plain it would look all right. If this was a reinforced floor, one would only see a beam with a 4-in. projection. One knows perfectly well that the proportion here is all wrong. The mistake made in most buildings is in attempting to make the beam or the column too small, simply to make it slender, and not take up so much space. Proportion all disappears, and you have got something which you know, if it were not for masking the beams in the floor, they could not possibly carry any of the weights put upon them.

Whether that comes into the question of the æsthetic treatment of concrete or not is another matter; I am talking purely from the engineering point of view.

Professor Beresford Pite, I think, is of opinion that the engineer should never attempt any architectural treatment in any of the works which he designs. With that I do not agree at all. I think that now reinforced concrete has come to the fore in the way that it has done, a great deal will rest with the engineer. I believe in collaboration between the engineer and the architect, but when you do have an engineer who has also had a moderate training as an architect, there is no reason why he should not combine both engineering and architecture, and I think it will be found that, especially in the case of very large buildings, in the shape of factories, etc., you will get as good a design from the engineer as it is possible to get from the architect.

One point was raised by the last speaker with regard to the question of the mortars that were used by the Romans. I think it is a well-known fact that in the old days the Romans simply used to slake their lime, generally for a period of two or three years before it was used, so that it became absolutely hydrated. There was no free lime in it whatever, and when it was mixed with the proper proportions of sand you then got a mortar that was almost equal to some Portland cement mortar of the present day, especially if they got some of the limestones slightly hydraulic as they did in some parts of the world.

Another thing is this: If you take lime and make it into a perfect cream, and also take some ordinary burned ballast that is well burnt, grind the ballast up and then mix it with the lime, in two months it has set hard like Portland cement. Whether that was known to the Romans in the olden days of mixing burned ballast with their slaked lime I cannot say, but it is known, especially in Gibraltar and especially in Moorish towns, that they have a mortar there of a hardness that even Portland cement of the finest quality cannot equal at the present day. It has never been discovered what the composition exactly is.

MR. BOLTON:—Is that the material which was used at Tangier?

Mr. WELLS :—I believe at Tangier, Gibraltar, and that vicinity.

Mr. BOLTON :—I do not know whether you know that in the reign of Charles II. a jetty was constructed, and when Charles II. decided to abandon Algiers, people were sent out from England to destroy this jetty, and they found it a terrible business owing to the hardness of the mortar.

Mr. WELLS :—It may have been ; I cannot say, but these works were erected in Gibraltar by the Moors. In some way the art of mixing mortar and its composition has been lost. There is no doubt that a lot of the mortars of the ancients were very good, as good as the best Portland cement mortars of the present day.

Mr. Chairman, time is getting late, others may like to speak ; but before sitting down I must thank Professor Beresford Pite for his most delightful lecture.

Mr. E. FIANDER ETCHELLS, F.Phys.Soc., M.C.I. :—I have been asked to speak, but this is a subject that I am not at all at home in. I have feelings, I have opinions, but it is no good my giving them to you, because they are merely the echoes of the opinions I have heard from architects. I came to-night with a perfectly open mind, but after seeing the examples of originality I shall henceforth have a predilection for something classical, preferably a modern development of something classical.

Reading through the paper and listening to the discussion, it would appear that the problem to-day divided itself into two parts—first, whether we shall consider reinforced concrete as a free material having its own laws and its own proportions and whether it shall be exposed naked to the world, or whether we shall only deal with it as a skeleton and clothe it with some other material. Until the architects themselves have decided into what category reinforced concrete is to be placed, I do not propose to express any opinions whatsoever. Architects seem to judge entirely by their feelings, but feelings are the most unreliable things in the world, as a physicist knows, and therefore I do not propose to add anything to the discussion which

might be cancelled by a change of my feelings to-morrow morning.

Mr. HERBERT SHEPHERD, A.R.I.B.A., M.C.I.:—I am sure Professor Pite's paper is one which will be received with every attention and consideration by members. It is, I take it, by such a paper as this, and by coming together and discussing the question from a strictly artistic point of view first and then hearing an engineer give his ideas on the matter, that the object of the paper is attained. It is in no combative spirit at all, but by genuine criticism and learning the different ways of viewing a new subject, that one is helped to a proper appreciation of the same.

There are one or two points with regard to this which I noted down, but I feel, coming after the previous speakers, there is very little to be added. With regard to the paper, the Professor remarked that no artist could exist who did not tune his harmonies for the public approval. Well, sir, I fancy that the great artists more often make harmonies before the public understand or approve them, and it is the man who creates the harmony first which the public afterwards approve of that becomes a famous artist. Mr. Bolton went into an intensely interesting matter with regard to Roman construction in concrete, but I think he was rather hard on poor Vitruvius. I made a few notes some time ago with regard to this particular subject, and with your permission I will refer to them.

Of course, reinforced concrete is the latest material which the science of construction has evolved. Concrete reinforced with the brick or tile was one of the constructional materials of the Romans, and Vitruvius Pollo recommends it as "one of the most valuable building materials," so one sees it is not quite so new after all. That was concrete reinforced with brick or tile.

In the House of the Vestals, at Rome, there is a concrete floor slab 14 in. thick of 20 ft. span; and the great builders of the Byzantine period used this material to construct those beautiful and stupendous domes which have ever since been the delight and wonder of the world. We have in reinforced concrete structural steel in the new form of bars or rods of

small section, distributed about and surrounded by concrete, the two forming a monolithic material with which a complete structure can be formed.

With regard to the question of jointing, I think it would be quite admissible, from a constructional as well as an artistic standpoint, to use joints in reinforced concrete. When you have a large building you cannot do it all in a day. It does seem to me, and I think it was suggested at one of our previous meetings, that it would be a very good thing to form a large joint or groove where the work stopped on a particular day. You get up to a certain height, and it is surely correct, provided it was treated in an artistic manner, to form a large groove or joint to show that was a day's work. In that way, would it not be a legitimate constructional feature treated in an artistic manner?

MR. WELLS :—How about when a hard frost came on?

MR. SHEPHERD :—I don't think Mr. Wells would go on building at all in a hard frost. In some of the reinforced concrete bridges there is a simplicity of line that, to my mind, is extremely pleasing, the sense of structural efficiency that you get is quite admirable; and those bridges are already giving us new forms of architectural expression.

Reinforced concrete is put forward as an economical material, capable of being rapidly constructed, qualities which are no doubt essential to some buildings of to-day. But I do not think those qualities are such as make them essential or even suitable for architectural buildings as an architect understands that term. They may be for warehouses and buildings of that nature—I mean where rapid building is required, but these are not monumental buildings, and one of the essentials of architecture is the sense of lasting. Perhaps it is owing to my lack of engineering training that I can never see that a 2-in. reveal looks like lasting as long as one of those great 6-ft. recesses that one sees in the Norman castles, for instance.

Further, with regard to the application of plaster, I agree and think Mr. Bolton is correct in saying that there is no reason why you should not take reinforced concrete and say, "This is the structural material on

which we wish to put a covering. We have a skin to cover our bones and muscles and our flesh and blood, and we cannot, if we would, object to it. That, I take it, is an example of what Nature does in a more or less artistic way to cover up the mechanics of our structures. There is no reason, so far as I can see, why you should not do the same thing with a building. It was done in the earliest example, I think, that we have of Greek art, the Minoan work at Knossos. The walls of the palace were built of unburnt brick or clay, and, knowing this would perish, they covered the walls all over with a thick coat of plaster, and on that they modelled figures. That is a possible suggestion for the æsthetic treatment of concrete, embellished with bas-relief, and sculpture on the lines of stucco-duro seems one way at least in which we might attempt to treat our reinforced concrete buildings.

MR. LUCIEN SERRIALLIER, M.C.I. :—In the older methods of construction, such as masonry and brickwork, buildings constructed in that material rely entirely for their stability upon the weight of the material of construction itself. With reinforced concrete the characteristic feature is tension, and I think the typical form of construction in that material is the cantilever. That conviction has been borne upon me by the illustrations of M. Hennebique's house we have just seen on the screen. Progress will take place in that direction ; we shall have larger spans and great cantilevers, while we must necessarily somewhat modify our ideas of proportion.

THE CHAIRMAN (Sir HENRY TANNER) then put the vote of thanks, which was carried with acclamation.

THE CHAIRMAN (Sir HENRY TANNER) (addressing Professor Beresford Pite) :—I have to convey to you the thanks of the meeting and myself for your very interesting lecture and for being so kind as to come down to us. M. Hennebique's house seems to be on the minds of some people. I was there two years ago when a deputation of the Concrete Institute went to Paris, and he was good enough to entertain us there and show us over his house. It is a very extraordinary construction, and as Mr. Scott said it was made principally to show the capabilities of reinforced

concrete, but there is no reason whatever why he should not have also tried to have made it look a little pleasant architecturally. It is an extraordinary building, especially the corner tower, which was evidenced by the picture shown to-night. At the same time it is a very useful house, very dry and very comfortable. He has a garden on the top, in fact, two series of gardens, one on the top of the tower as well as on the general roof, and he and his family spend some of their time up there, I believe, and vegetables are grown and fruit trees, and they have also got a greenhouse. It is a very convenient house inside, and that is the great point, I suppose.

Otherwise in Paris I have not seen anything that I should care to repeat here in the way of reinforced concrete architecture. Mons. Hennebique's offices in Paris itself are certainly nothing to copy, although they are quite convenient. It struck me that they had cost him a great deal more than if he had built them under ordinary construction. I will now ask Professor Beresford Pite to make any remarks he wishes in reply.

PROFESSOR BERESFORD PITE :—I beg to thank you, sir, very much for the vote of thanks. It has been a pleasure to have had the opportunity of discussing this matter with you. It is quite interesting to find how difficult it is on artistic matters for people to think simply, and to believe what one says when one tries to speak simply. I quite despair of Mr. Scott. He has gone out of the room, so I cannot deal with him quite with that air of friendliness which, of course, a report does not convey. He quite deliberately stated what he thought was my view. My view, as expressed in print, is exactly contrary to his statement. I can just refer you to it. The paper is quite clear, "The only method by which definite progress in an architecture of concrete will be possible to us is by the scholarly and critical employment of the traditional plastic forms of architecture." Now, Mr. Scott seems to have been under the impression that that was not my opinion, but it is, and I think this will answer some of the interesting remarks made by Mr. Wells, or Mr. Shepherd, who supported the idea that an engineer who gives attention to architec-

ture could deal with the subject, and that it is possible to imagine certain principles of proportion and apply them to the new material irrespective of architectural examples in other materials. I want to say flatly, clearly, and plainly, it is not, and there is an end of it ; simply, it is not. It is not possible to imagine a system of proportions for a new material apart from those ideas of proportion which you derive from others.

Mons. Hennebique's house proves this up to the hilt. You may enjoy all the consequences from this absence. If you depart from the accepted proportions which you derive from traditional architecture you are completely at sea. You may talk about your surface ; you may imagine that an occasional joint every other day or every other week during construction, when there is no frost, will help you, but it will not ; you are in the open sea. If you begin to study architecture systematically, you will find that the sweet little exercises with which you employ yourself on such huge works are just little exercises in ignorance.

May I just again suggest that the point of this subject is that the æsthetic or the architectural treatment of concrete buildings wants serious study, and it can only be undertaken by seriously laying hold of the principles of architecture, and that a sort of sporting shot at it, a sort of relying upon the average engineer's acquaintance with architecture, who does not wish to make a fool of himself, is not enough. You may take it for gospel, if you please, there are rules and laws easily deducible with regard to the principles of architectural beauty ; as easily deducible as the laws which I think Professor Hosking deduced from Hadrian's Villa at Rome as to the legal thickness of brick walls. We have the facts, we lay the facts side by side, the synthesis emerges, and when once you become conscious of it you find that it is a subject that repays study, because its principles can produce results when those principles are applied.

Now, I say, apply the principles of architectural tradition to concrete ; the material itself will act through its texture upon those principles and will mark them for its own. You are perfectly at liberty to say you see no harm in marking reinforced concrete in a cantilever bridge with the joints that

represent a stone arch construction. Do it, and be hanged is about all that I can say—(laughter)—but it is not architecture and it is not engineering, and it is not an æsthetic treatment of concrete architecture.

Now, let me just beg pardon for trying to speak plainly, quite plainly, but let me again urge that it is a large subject which needs careful study.

I am very much obliged to Mr. Bolton, in his most interesting and valuable speech, for reminding us of that little book of Garbett. Now, Garbett was a man who wrote before Ruskin, and as a preacher of sound architectural doctrine he will survive Ruskin, and his English is tolerable; as good as that of an encyclopædia. This little book is still on sale; it is well worth attention, and will help to open eyes to the great interest and charm of the subject.

Mr. Scott asked a question as to the vaulting of a church in reinforced concrete. Well, I have the drawings in my office at the present moment of a big cathedral in a tropical climate. I took the trouble to work out a reinforced concrete vault. You may smile at my foolishness, but I did. I found, of course, it ceased to be a vault; it was merely putting a lid on to a box shaped like a series of dish-covers. There was no need for buttresses, or or for any features usually characteristic of such a building, so the problem became altogether a new one. I will frankly confess that I abandoned the reinforced concrete idea, not on that account. I fear my professional friends when this appears, because I have serious doubts as to the advisability of employing that material in a climate subject to extremes. That is the reason why I hesitate to use it in a position where failure would have been a very serious difficulty. Also the expense; but that was not the determining factor.

Now, we artists are difficult people to please, but I am going to have a crack with Mr. Bolton. He spoke of that monstrous Baldachino at St. Peter's at Rome, made out of the flat plates of bronze from the roof of the Pantheon. Mr. Gilbert, the distinguished sculptor, once said to me that this is the most beautiful thing in Christendom, so I cannot let Mr. Bolton call it a monstrosity without citing some other authority other than an architect or an engineer.

As to Byzantine architecture, I do not quite follow the reference to its being an architecture of reinforced concrete—that is to say, of concrete only reinforced by brickwork. Am I not right in thinking that the Byzantine vaults are wholly of brick at S. Sophia, Constantinople, the structure of which is not thick enough, I suppose, to admit that form of construction? It is possibly of a ribbed brick construction—a series of forty ribs from the rim to the crown. The dome fell three times, and was rebuilt within the century in its present form. In the result it is practically a brick-ribbed dome with brick filling.

Perhaps I might remark that I am entirely at one with Mr. Shepherd as to the artist and harmonious tunes, but that does not issue in an attempt to evoke sympathy. Is not art, is not the real basis of art, that it is an appeal from you to others? If you are going to appeal to a vacuum, you had better find your vacuum in some padded room. (Laughter.) It seems to me that is the place for it. The architect is especially charged to appeal to the wide public who walk the street, and the engineer equally because he is a great builder.

And then there was one very interesting short remark as to the different categories of construction and of art, of fact and of feeling, and that feelings are shifty, dubious, and change to-morrow and disappear. It is not true. Venus of Milo still controls our feelings. The work of all the great artists has this in it, that their feeling is permanent. What is ephemeral is gone. The engineer's feelings in architecture do go ; the architect's do not. (Applause and laughter.)

The meeting then terminated.

TWENTY-FOURTH ORDINARY GENERAL MEETING

THURSDAY, MARCH 14, 1912

THE TWENTY-FOURTH ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held in the Lecture Hall at Denison House, 296, Vauxhall Bridge Road, London, S.W., on Thursday, March 14, 1912, at 8 p.m.,

MR. E. P. WELLS, J.P., M.C.I., in the Chair.

The following were elected members of the Institute :—

MR. VICTOR ALDEN, London.
MR. REGINALD BIRKETT, Manchester.
MR. ALFRED CORDERY, London.
MR. ALEXANDER THOMAS CRANMER, Egypt.
MR. ROBERT GILLIES, Kingston, Jamaica.
MR. CHARLES ALBERT KING, Assoc. Royal College of Science (Ireland), A.M.I.Mech.E., Assistant Professor of Engineering at Heriot-Watt College, Edinburgh.
MR. ALFRED WADSWORTH LOVELL, Hull.

MR. A. C. HUGHES, Wokingham, Berks, who had resigned in November, 1911, was reinstated as a member.

THE SECRETARY (MR. H. KEMPTON DYSON) announced that MR. FREDERICK JOSEPH FINDON, of London, had been admitted as a Student of the Institute.

MR. REGINALD RYVES, Assoc.M.Inst.C.E., M.C.I., then read his paper on " High Dams of Great Length " as follows :—

HIGH DAMS OF GREAT LENGTH.

THE MASS GRAVITY TYPE AND THREE TYPES OF SPAN DAMS.

By REGINALD RYVES, Assoc.M.Inst.C.E., M.C.I.

When an engineer undertakes a special study of any kind, he usually finds that certain considerations vitally affecting the problem before him have not received quite as much attention as their importance demands, and he sometimes finds, too, a new path of study, or investigation, or some new way of applying well-established principles. In both cases he may gain much by putting his views before his fellows, and their opinions and criticisms will help to put these matters in the true perspective, to confirm or correct his opinion as regards what he thinks has been neglected or not fully grasped, and to point out where his new path has already been well trodden or where it leads to an impassable chasm.

The special study which the author of this paper undertook, and on the results of which this paper is based, was a study of high masonry dams of such length that they may be regarded as dams proper, and in no sense as structures partly held up to their work by the sides of the river valleys. While the great size of the two dams contemplated rendered economy of material an important matter, this was absolutely dominated by the still more important consideration that the dams must be in all respects stable and lasting. It was also desired to avoid as far as possible the use of Portland cement.

Leaving aside all other considerations arising out of the study, this paper is confined to those connected with the building of dams of a great length, the whole of which length is more than 140 ft. clear of the ground, and a part of which may be as much as 180 ft. or more to hard rock. The height of 185 ft. clear was adopted for purposes of calculation. The subject of the paper is, further, kept within somewhat close limits by the condition that the highest calculated maximum stress in the masonry must not exceed 12 tons per square foot, at any rate by

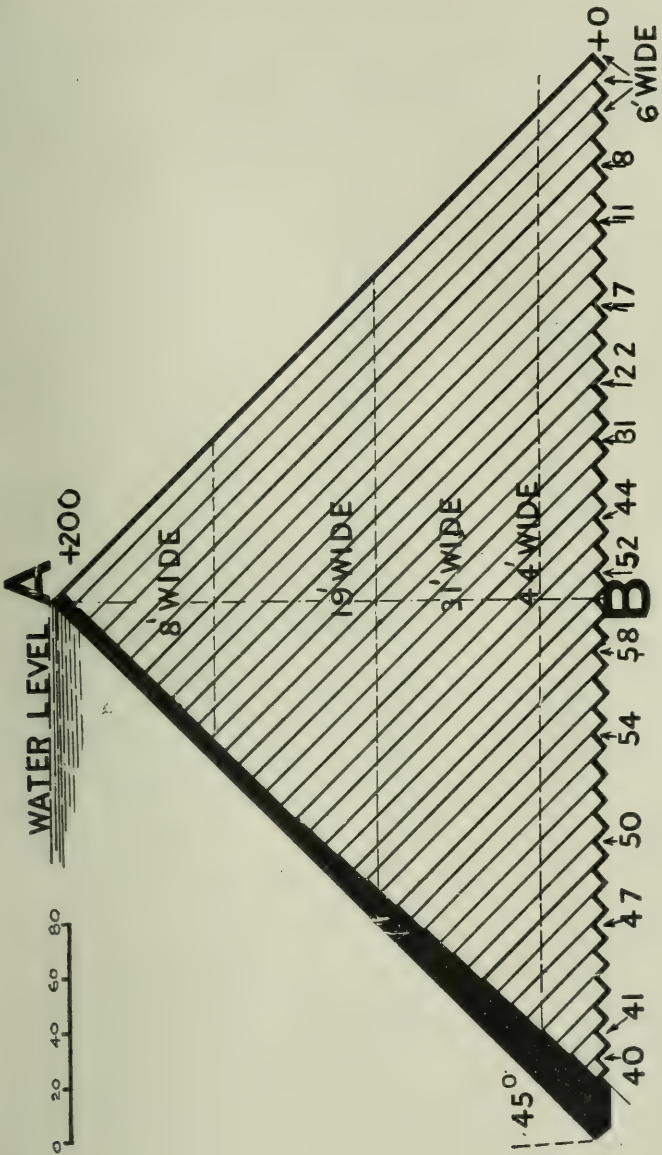


FIG. 1.—Thrust Buttress Dam: Elevation of Buttress and Section of Arch.

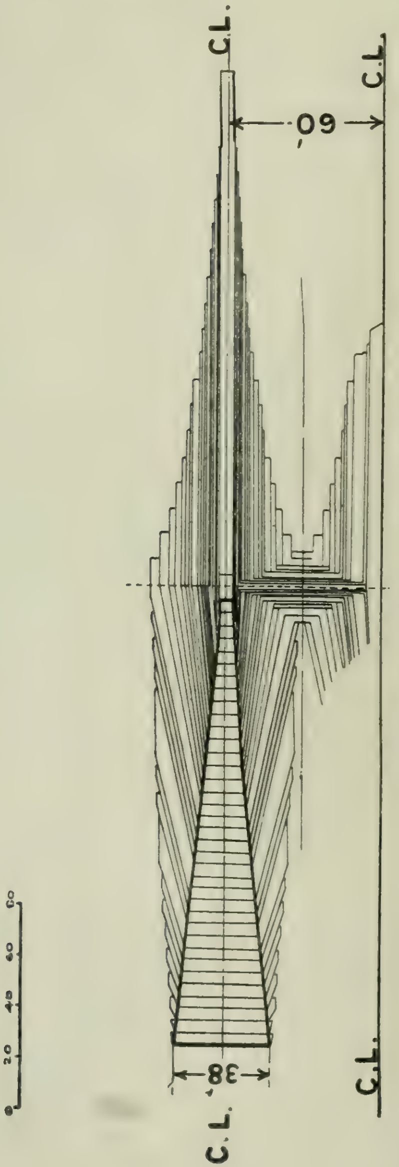


FIG 2.—Thrust Buttress Dam : Plan.

Bouvier's computation, though by Unwin's computation a somewhat more severe stress may be allowed.

Before setting forth the definite propositions which, it is hoped, may concentrate discussion, it may be well to point out that there are four distinct types of dams for wide valleys, and entirely excluding the dam which is a single arch, in plan, and the dam which is, in

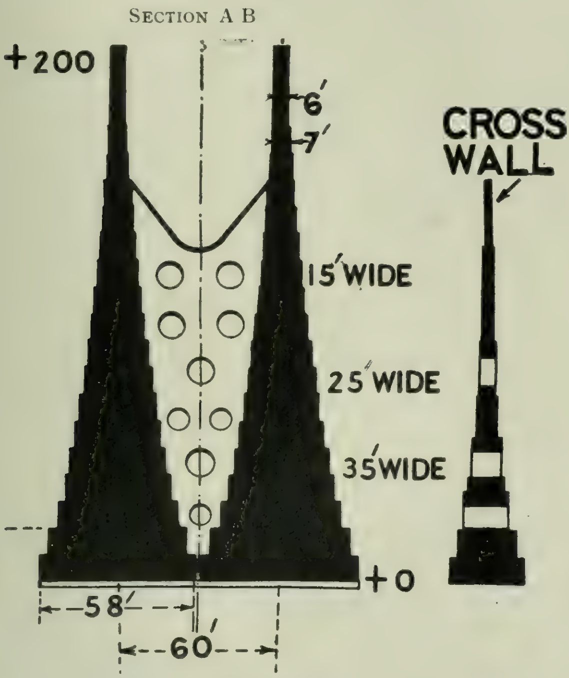


FIG. 3.—Thrust Buttress Dam.

its lower part, practically a plug in a gorge. The four types are :—

1. The mass dam proper, designed on the ordinary theory.

2. The parallel slice dam, which is designed in exactly the same way, but with more concentrated water loads.

3. Captain Garrett's type, or the dam of arches in

which the weight of the arches is partly taken into account, but the dam otherwise designed as a gravity dam with concentrated water loads.

4. The author's proposed thrust buttress dam of arches, in which the whole of the water load is taken by masonry in direct compression, and neither the weight of the buttress nor the weight of the arch is taken into account as regards stability, except for resistance to sliding bodily when the ground is comparatively soft.

As regards the first class, the mass gravity dam, we find that for high dams, above 150 ft., the maximum stress increases very rapidly indeed, and that to build a dam 200 ft. high we must exceed a stress of 12 tons per square foot by Bouvier's computation, and greatly exceed it by Unwin's computation.

For a dam 185 ft. high, and where α is the angle of the resultant with the vertical and ϕ the angle of the masonry face at the toe with the vertical, we get, in a normal design, with masonry of specific gravity $2\frac{1}{4}$, and with p (calculated by the usual rule) as followed by Wegmann and others, such figures as—

$$p = 7{\cdot}85 \text{ tons per square foot}$$
$$p \sec^2 \alpha = 10{\cdot}92 \quad ,, \quad ,,$$
$$p \times \sec^2 \phi = 17{\cdot}90 \quad ,, \quad ,,$$

Higher stresses than 12 tons per square foot by Bouvier's computation have been allowed underground, but there is no precedent for a long, straight dam which is considerably over 150 ft. clear of the ground for any considerable length.

Coming now to the second class, which is one type of the dam of spans, and may be a good type to build when it is necessary to leave ample waterway during the building, we find that its height is limited by two considerations. First, we cannot build truly parallel slices of more than some limiting height without side buttresses. If we slope the sides the strict theory no longer holds good, and we shall find that we are logically led to Captain Garrett's type, in which the weight of the arches is partly counted upon for stability. The other limiting factor is that the concentration of water loads in these separated slices increases both α and ϕ so much that we get very high

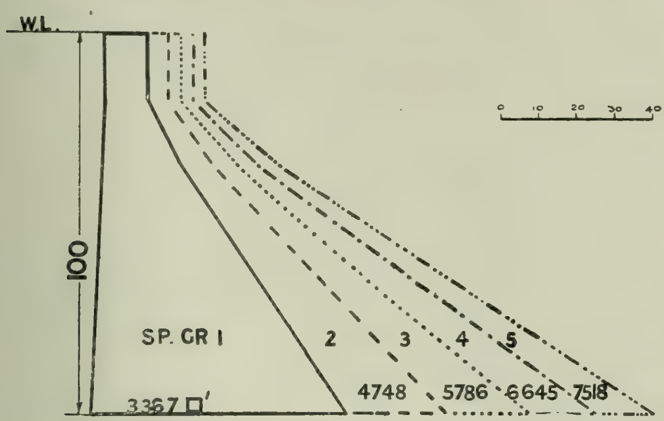


FIG. 4.—A Parallel Slice Dam: Gravity Buttress.

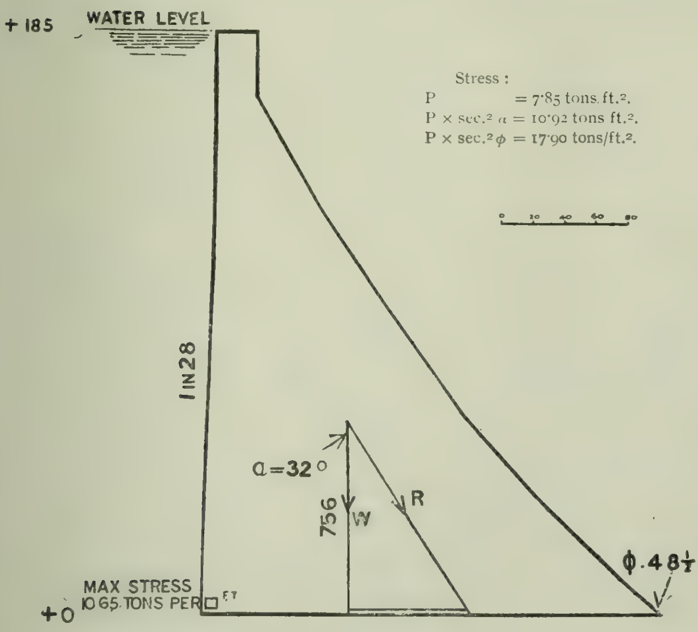


FIG. 5.—A Mass Dam.

maximum stresses. Thus, for a dam $\frac{1}{3}$ solid and $\frac{2}{3}$ span, the calculation being made as for a mass dam for a liquid with specific gravity 3, we get, for a height of $162\frac{1}{2}$ ft. and specific gravity of masonry $2\frac{1}{4}$—

$$p = 4{\cdot}72 \text{ tons per square foot}$$
$$p \times \sec^2 \alpha = 9{\cdot}10 \quad ,, \quad ,,$$
$$p \times \sec^2 \phi = 25{\cdot}39 \quad ,, \quad ,,$$

Although, as Professor Unwin has pointed out, we need not believe that such a high stress as the last noted actually exists, we are obliged to take the theory into account in comparing one dam with another, at any rate until some one can give us a modification for very flat angles.

It is clear that though this type may be very economical for heights up to 100 ft., and may be used up to 150 ft., if we are not afraid of $\sec^2 \phi$, and build it half gaps and half slices—gaps and slices of equal length along the dam—it does not help us in designing a very high dam.

It may be noted that with a dam half gaps, the specific gravity of the liquid of calculation being 2, we get, for a dam $162\frac{1}{2}$ ft. high and specific gravity of masonry $2\frac{1}{4}$—

$$p = 5{\cdot}43 \text{ tons per square foot}$$
$$p \times \sec^2 \alpha = 8{\cdot}91 \quad ,, \quad ,,$$
$$p \times \sec^2 \phi = 18{\cdot}29 \quad ,, \quad ,,$$

If we can adopt some method of combining the use of $p \sec^2 \alpha$ with that of $p \sec^2 \phi$, we might build such a dam.

Since the weight of the water apron is not taken into account at all in this type, it is one which is adapted for use with thin arches of very strong stone, or a ferro-concrete beam and slab arrangement, for the water apron.

The third type, in which the weight of the arches is partly taken into account, has been successfully used for the Agar dam, in Rajputana, a dam 68 ft. high, designed and built by Captain A. ff. Garrett, R.E.

The indeterminate nature of the stresses is, however, against this type for great heights, but with

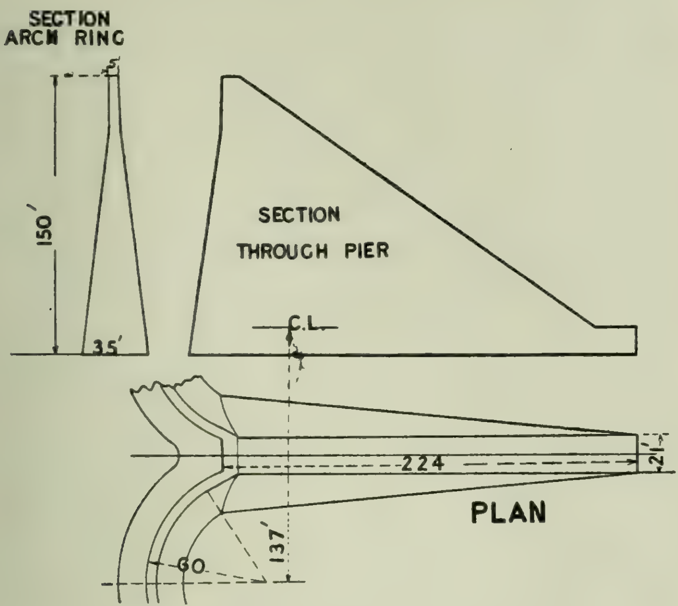


FIG. 6.—Garrett's Design for a 150-ft. Dam.

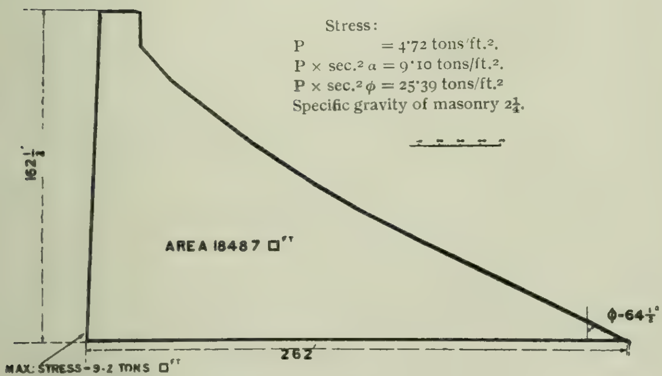


FIG. 7.—A Parallel Slice Dam, ⅓ solid, ⅔ gap.

small gaps and large buttresses it has certain advantages. For instance, with the bases of the buttresses merging together it would be a very good type for through-sluices, or for a suitably arranged overflow.

Captain Garrett has made a design for such a dam 150 ft. high, and the question whether it may be built up to heights of 200 ft. above-ground may, perhaps, be left to his initiative.

For a height of 100 ft., a comparison of costs shows that under certain conditions the advantages of clear openings totalling $\frac{2}{3}$ the length, and of more definitely calculated stresses, could be attained by building a parallel slice dam at an additional cost of 20 per cent. compared with Captain Garrett's type.

We now come to the fourth class, the author's typical design for a thrust buttress dam. The best slope for the water face is, under normal conditions, 45°, and the dam then consists of inclined arches, of increasing thickness with increasing depth sloping at 45°, the abutments resting against the up-stream face of the buttresses, which are built up of layers all inclined at 45°, the thickness depending upon the material used, and the width of each layer being such that the thrust upon it is the maximum allowed thrust.

The calculation of thrust is made by adding the water load transmitted to any plane parallel to the face to the resolved part of the weight of masonry above the plane in question, the same method of calculation being adopted in every part of the buttress. The resolved part of the weight of the arch is, in each case, added to the water load. The water loads are thus transmitted by direct thrust, the layers not being bonded together, but left free to take up the deformation under the water load by sliding on one another. If the rock will not take the load at an angle of 45°, the water face may be made flatter and longer, and the buttresses, always at right angles to it, steeper and shorter. The typical design is, however, that with a 45° slope. Every part of the dam is subject to the same stress except that the top layer of the buttress and the upper part of the arch ring may have, respectively a greater width and a greater thickness, the minimum in each case for the materials used.

This adoption of a general stress, instead of one

varying from nearly zero to some maximum, is an important element of economy.

Comparing this dam with a mass dam, under certain conditions of site and costs of material, the following, for dams $162\frac{1}{2}$ ft. high, was found :—

Mass dam, maximum pressure (Bouvier) 10 tons per square foot.	Masonry, 100 units.
Thrust buttress dam, minimum arch thickness 6 feet, stress in arches 15 tons per square foot, in the buttresses 10 tons per square foot.	95 units.
Thrust buttress dam with a minimum arch thickness of 4 feet.	92 units.

The difference would be considerably greater if we made, for the mass dam, $p \sec^2 \phi = 10$, or even $p \sec^2 \phi = 12$.

If the rock is not strong enough to take as high a maximum stress as that allowed in the buttresses, the layers can be footed out to a greater width below ground-level, subject to a limitation by the height and the allowable stress, upon which depends the amount of spare distance between the buttresses. Similarly, even if the rock may be subjected to a stress as high as that in the buttresses, there is, for each stress allowed, a limiting height, which brings the buttresses together at their bases. With a stress of 10 tons per square foot the height is a little over 200 ft., and with a stress of 16 tons per square foot, about 300 feet.

Such a dam may be built of materials which are not suitable for the rubble masonry or mass concrete of a mass gravity dam. For instance, slabs of limestone or hard shale may be used, both in the arches and in the buttresses, with their bedding planes at right angles to the direction of thrust, or it may be built with blocks of concrete. On the other hand, it can be built of rubble masonry, or the layers can be built up from their lower ends, of rammed concrete between rubble walls.

On the whole, there is greater choice of materials than in the building of a mass dam, greater choice of

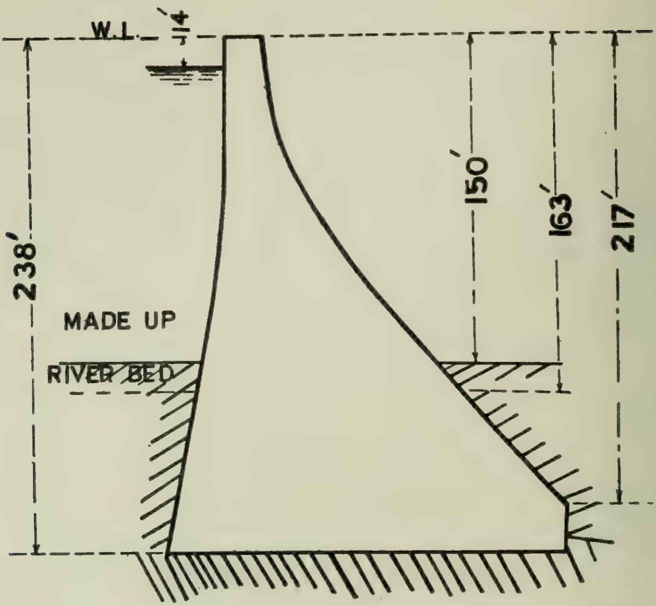


FIG. 8.—New Croton Dam.

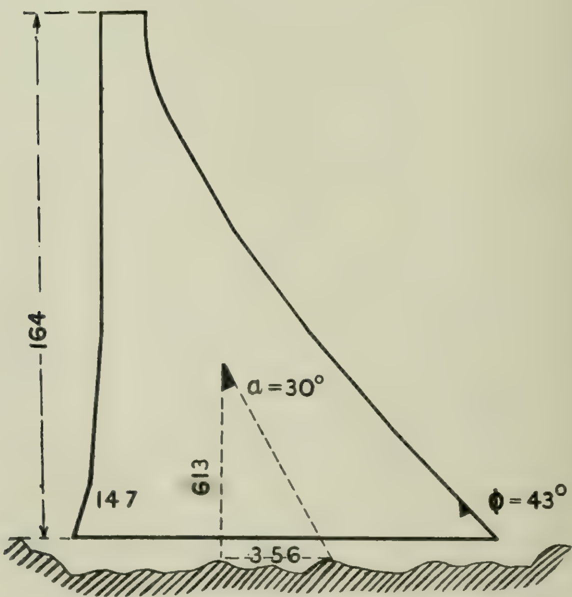


FIG. 9.—Chartrain Dam (Masonry weighs 150 lbs. per cu. ft.).

methods, and, as in the case of any dam of spans, fewer difficulties in the management of the river and hardly any trouble from expansion or contraction.

The definite propositions which the author puts forward are :—

1. That there is no precedent for the building of a mass gravity dam in an unassisted length more than 150 ft. clear of the ground.

2. That our present ideas as to maximum stresses allow of the building of such a dam for heights only slightly in excess of this.

3. That since the improbability of the stress actually reaching $p \sec^2 \phi$ increases as the slope at the down-stream toe is flattened, we may, for heights above 150 ft. and for angles flatter than 45°, allow one maximum computed stress for $p \sec^2 \alpha$, and a computed stress for $p \sec^2 \phi$, some 50 per cent. higher. This applies both to mass gravity dams and to parallel slice gravity dams, and perhaps also to Captain Garrett's battered buttress type.

4. That interrupted dams, the gaps being spanned by horizontal or inclined arches, or by beams, offer the important advantages—

(*a*) Economy of material ;
(*b*) Absence of contraction cracks and temperature stresses ;
(*c*) Maintenance of waterway during construction ;
(*d*) Cheapness of sluices ;
(*e*) In some cases a wider choice of materials and of methods of building ;
(*f*) And that the interrupted dam, or dam of spans, may be considered as an alternative to the mass gravity dam for great heights, especially as regards the height clear of the ground.

5. That the author's design for a thrust buttress dam is suitable for heights up to 200 ft., with materials allowing of a compression stress of 10 tons per square foot and up to 300 ft., if a stress of about 16 tons per square foot be allowable.

6. That none of the dams at present built are thrust

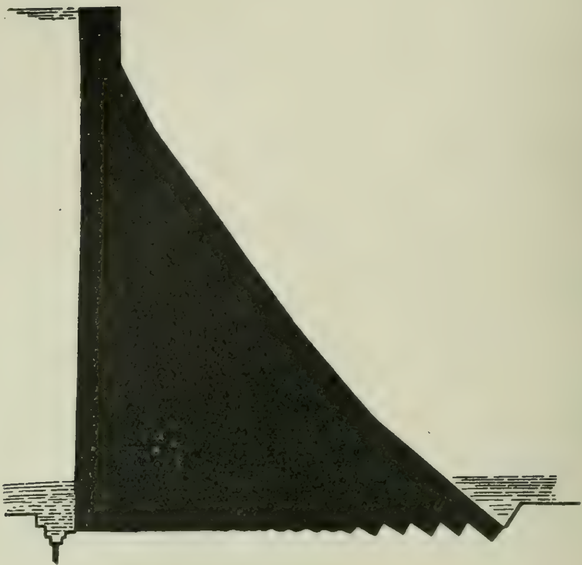


FIG. 10.—Proposed Typical Foundation for a High Dam.

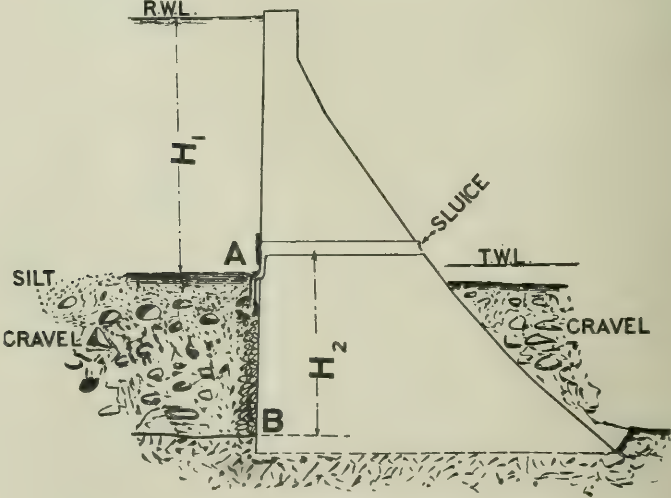


FIG. 11.

buttress dams, either as regards the method of building or in practical effect.

7. That in order to avoid tension near the upstream toe of a high mass dam, or of a gravity buttress in a dam of spans, it is desirable to make the connection with the rock somewhat as follows :—

The upstream third of the base a flat surface with no bonding and *no trench;*

The middle third bonded, but not deeply trenched ;

The downstream third effectively bonded with the rock cut in faces at right angles to the thrusts of the masonry.

TABLE I.

DAMS 162½ FEET HIGH.

Comparison of Parallel Slice Dam (Mr. Ryves) with a Mass Dam, the height being 16½ ft.

The specific gravity of the masonry 2¼ in every case. Maximum stress allowed, 10 tons per square foot in the buttress and 15 tons per square foot in arches.

Type of Dam.	Specific Gravity of Liquid.	Archwork for 1 R.Ft.	Piers with Buttress Masonry for 1 R.Ft.	Total for 1 R.Ft.	Percentage.
Mass Dam	1	—	—	9,453	100
Parallel Slice Dam...	2	626	7,491	8,117	85·9
Do. ...	3	1,080	6,834	7,916	83·7

8. That when a high dam is to be built with a large part of its total height from foundations below the bed of the reservoir, it may be worth while to relieve that part of the upstream face from water load by directly draining it through the dam.

9. That dams in the tropics, or near the tropics, with downstream faces towards the Equator, or facing east or west, may with advantage be provided with temperature skins to a depth depending on the extent to which daily or annual changes in temperature deprive the outer shell of the face of its value as material resisting compressive stress.

TABLE II

Dams 100 Feet High.

Comparing the Cost of Parallel Slice Dams 100 ft. High with a Mass Dam of Ordinary Section.

Max. stress allowed in the buttresses and in the mass dam = 10 tons sq. ft. As the stress allowed is increased, the relative economy of the parallel slice dams is greater.

Specific Gravity of Liquid per Calculation.	Thickness of Pier.	Length of Pier at Top.	Length of Pier at Base.	Span 60 Ft. Clear in each Case.					Span 60 Ft. Clear in each Case.					Span 30 Ft. Clear in each Case.					Remarks.
				Allowed pressure in arches = 15 tons sq. ft. Extra thickness allowed for temperature changes in arches = $1\frac{1}{2}$ ft. Rate of buttress masonry = R per 100 cu. ft. Rate of archwork = 3·2 R per 100 cu. ft. Rate of excavation = R per 1,000 cu. ft.					Allowed pressure in arches = 20 tons sq. ft. Extra thickness allowed for temperature changes in arches = 1 ft. Rate for buttress masonry = R per 100 cu. ft. Rate for archwork " = R per 100 ". Rate for excavation " = R per 1,000 "					Allowed pressure in arches = 20 tons sq. ft. No allowance is made for changes in temperature in arch rings. Rate for buttress masonry = R per 100 cu. ft. Rate for archwork " = R per 100 ". Rate for excavation " = R per 1,000 "					
				Cost per Running Foot of Dam.					Cost per Running Foot of Dam.					Cost per Running Foot of Dam.					
				Arch-work.	Buttress Masonry	Excavation.	Total.	Centage.	Arch-work.	Buttress Masonry.	Excavation.	Total.	Centage.	Arch-work.	Buttress Masonry	Excavation.	Total.	Centage.	Ordinary Mass Dam.
1	—	12	67·11	—	33·67 R	0·67 R	34·34 R	100	—	33·67 R	0·67 R	34·34 R	100	—	33·67 R	0·67 R	34·34 R	100	Max. stress = 8·9 tons sq. ft.
2	60	17·2	94·5	6·99 R	24·18 R	0·53 R	31·70 R	92·3	4·44 R	24·18 R	0·52 R	29·14 R	84·9	—	—	—	—	—	Max stress = 10 tons sq. ft.
2	30	17·2	94·5	—	—	—	—	—	—	—	—	—	—	1·40 R	24·18 R	0·50 R	26·08 R	77·0	Ditto
3	30	20·8	116·1	9·32 R	20·47 R	0·47 R	30·26 R	88·1	5·02 R	20·47 R	0·44 R	26·83 R	78·1	—	—	—	—	—	Max. stress = 9·4 tons sq. ft.
3	15	20·8	116·1	—	—	—	—	—	—	—	—	—	—	1·89 R	20·47 R	0·42 R	22·78 R	66·4	Ditto
4	20	24	135·5	10·48 R	18·45 R	0·42 R	29·35 R	85·4	6·60 R	18·45 R	0·40 R	25·51 R	74·3	—	—	—	—	—	Max. stress = 9·65 tons sq. ft.
4	10	24	135·5	—	—	—	—	—	—	—	—	—	—	2·10 R	18·45 R	0·37 R	20·92	60·9	Ditto

10. That a long and high mass dam may usually be, with advantage, built with gaps in the masonry across the length, these gaps being filled when the temperature of the dam is judged to be nearly at or a little below its future mean temperature. If cracks are specially to be guarded against, the gaps may be filled at the end of the cool season and after the temperature of setting has subsided—that is, when the average temperature of the masonry is at its lowest.

11. That the grading of material in a large dam should be such that the large stones are not "plums" or displacers, but play the part of the stone in ordinary concrete.

The general theory of arched dams is explained, and Captain Garrett's type described, in Professional Paper of the Royal Engineers. Fourth Series, Vol. II., Paper No. 1. By Captain A. ff. Garrett, R.E.

The author's studies are fully reported in a "Note on Mass Dams and Dams of Arches," a Madras Government paper, P.W.D. (Irrigation).

The author's statement of the general problem and a concise description of his type design for a thrust buttress dam will be found in the *Engineer*, February 24 and March 3, 1911—"The Problem of the High Masonry Dam."

DISCUSSION.

MR. CHARLES F. MARSH, M.Inst.C.E., M.C.I. :—Mr. Chairman and Gentlemen, I think Mr. Ryves is to be very much thanked, I will not say congratulated, for bringing to this Institute a paper of this nature. It is a very high-class paper, and although we are accustomed to very high-class papers, still I must say that I think this paper is one of the best which we have ever had before us.

I should like to ask the author—I am not up in Indian engineering—about the parallel sliced dam. Am I to understand that it is formed of buttresses with parallel sides in contradistinction to ones with wedged-shaped buttresses, and that therefore the arches are of the same span all the way down? I do not quite understand how the arches of the parallel sliced dam abut on to the slices.

With regard to the height of high masonry dams, I do not quite understand Mr. Ryves and think he must have made some mistake. In the case of the New Croton Dam, for instance, the author has stated 238 ft. as the height. Only yesterday I was reading the Proceedings of the American Society of Engineers, and it was stated there, distinctly, that the New Croton Dam was 297 ft. high from its foundations. I presume that the height given by Mr. Ryves is the sort of average height throughout the high portion of the dam. The new Olive Bridge Dam is a dam of the considerable height of 252 ft., and I believe it is a dam of considerable length, and I daresay the 252 ft. extends for a considerable portion of the length.

The reason I bring this forward is that I understood from the paper that the author seemed to imply that an ordinary mass dam, 200 ft. in height, was almost impossible for any considerable length.

The form of dam which the author advocates is, of course, new—it is new to me, at any rate—and it appears to be an extremely good form of dam and an extremely economical one. It calls to my mind, of course, the section of the reinforced concrete dam. Personally, I have never seen anything in the nature of a masonry dam, using masonry in its larger sense, of anything like this form. His dam is like the reinforced concrete dam of the ordinary type in that it has a water face with slopes of 1 to 1 or even flatter, supported by buttresses, although the buttresses are very wide at the foundations. It has the advantage which the reinforced concrete dam possesses, that if there is considerable leakage past the front toe the pressure can be relieved from acting on the foundations by letting the water flow freely through them. This relief cannot be so efficient in the case of Mr. Ryves's dam as in the case of a reinforced concrete dam since his buttresses extend over a considerable portion of the foundation.

The author stated that a reinforced concrete dam could not be built to any considerable height. I have not gone into the question at all—I daresay he has—but I should rather like him, if he would, to state the limits to which the ordinary type of reinforced concrete dam with a slab and buttresses could be

built. The great advantage of a reinforced concrete dam, or one of the great advantages, is this, that there is absolutely no pressure on the outer side of the upper stream face, because if you have a wall along the toe down to the impervious strata, any upward pressure is relieved at once by letting it drain through the base of the dam and so down stream. Another advantage is that the pressure on the foundations is more evenly distributed than in the case of a gravity dam. The pressure distribution diagram is not in the form of a triangle, it is almost in the form of a rectangle, and approaches the rectangle more nearly as the depth of water increases. In the case of Mr. Ryves's dam, a similar distribution of pressures occurs at the buttresses. I have been working out some calculations with respect to the vertical component of the pressures under the apex of Mr. Ryves's dam, but I made a mistake at the beginning, so they are not much good. Has the author taken into account the vertical component of the pressures on this dam. What I mean is, that according to the height of the dam there will be a certain weight of masonry underneath the apex which will be distributed over the full width of the buttresses, and there will also be a considerable pressure due to the water on an inclined face of 1 to 1. Although the vertical components of the pressure at the base are more evenly distributed by there being a flatter slope on the water face, they are also greatly increased. I do not know whether he has ever taken out—I suppose he has—the vertical pressure which he would get directly under the apex of the dam with reservoir full. There are one or two things I should rather like to know. One is as to the draining of the upstream face below the bed of the river or the surface of the ground. Of course in India I do not know what the conditions are, and you may get a waterproof sealing of the surface of the ground very soon, but in England it would, of course, be an extremely dangerous thing to put drains through at the bottom of a masonry dam, it would probably empty your reservoir. I suppose that would not occur in India.

I also do not quite understand what he meant about "plums." I have always thought that the great thing

to be aimed at when you are putting in big blocks of stone in concrete as "plums" was to keep them apart, and properly surround them with the ordinary concrete, the concrete being mixed in the proper proportions, to prevent leakage of water. It is extremely economical to put in large blocks of stone and the concrete is none the worse for it, but I should have thought that these stones should certainly be kept from four to six inches apart at the least.

Once more I should like to thank the author very much indeed for his exceedingly able paper.

Mr. EWART S. ANDREWS, B.Sc.(Lond.), M.C.I. :—Mr. Chairman and Gentlemen, I am in the happy position, or unhappy position perhaps, of never having had the privilege before of listening to a paper read before the Concrete Institute. I am unable, therefore, to compare its merits with those of its predecessors, but this paper does appeal to me as being a most valuable one, and one upon which I, for one, would like to obtain some further information. My own knowledge on the subject of dams is restricted to the theoretical consideration of the case. I have had no experience of the practical construction of them, but I had the good fortune of being at University College some eight years ago, working with Professor Pearson at the time that he was working with Mr. Atcherly on the subject of the stability of dams, and, as you are probably aware, the result of his investigation was a paper which raised a very large amount of discussion amongst those interested in the construction of dams. For that reason I have always taken a considerable interest in the theoretical aspect of the problem, and it has always seemed to me that the stability of dams is, from a theoretical point of view, one of the most troublesome problems which the structural engineer has to consider.

The whole of the ordinary theory of dams is based upon an assumption that the masonry is an elastic material, which assumption is probably considerably far from the truth. As far as I know, nearly all the dams that have been designed have been based upon the well-known law of the Middle-third, and it has always seemed to me to be a very happy accident if it happens to agree with the result in practice, and

it is on account of the extreme difficulty of the satisfactory theoretical treatment of the ordinary gravity dam that it seems to me that we want to be rather careful how we approach the subject.

I notice that the author has made comparative calculations with the Bouvier and Unwin theories. I should like to know his opinion of the Bouvier and Unwin theories. Perhaps he would not mind explaining to us how they are obtained. I think I understand, but they seem to me to be based upon a fallacy. At any rate, I would like to have some further information as to this point.

I am rather surprised that some reference has not been given to the consideration of the stresses in dams, based upon the points which were raised by Professor Pearson in the paper to which I have referred. That paper was intended principally to direct attention to the tensile stress in the toe of the dam, caused by the upward pressures acting upon the toe as a cantilever, and thus causing the tensile stress in that way. Later on Professor Pearson carried out some further experiments on jelly models of dams, and although he found very great difficulty in getting results that were sufficiently consistent to enable him to enunciate any scientific theory, his result was, that one of the most important points to allow for was the bonding of the dam to its substratum, not on the side shown in Fig. 10, but on the opposite side. I would like the author to say whether he considers Professor Pearson's investigations insufficient in that respect.

Now, coming to the particular form of dam for which the author is responsible, I must say that although I had the opportunity of reading the paper referred to, I was unable to give it the attention which the matter deserves, and I think that many other members would like to have some further explanation of the manner in which the stresses are calculated in this form of dam. I think the author, perhaps, has made the mistake of imagining that all of us know as much about the subject as he does ; and I am very sure we should very much appreciate some further explanation in that direction. I think, sir, those are all the remarks I have to make. I would like to add my thanks to those of the previous speaker for this very interesting paper.

Mr. E. FIANDER ETCHELLS, F.Phys.Soc., M.Math.A., A.M.I.Mech.E., M.C.I. :—Mr. President and Gentlemen, I should like to support Mr. Andrews in asking for the derivation of the formulæ. It is quite apparent from the paper that Mr. Ryves has given more attention to the question of high dams than most of us. We, in London here, have access to our libraries and our text-books in which the data are given and can verify the formulæ and their derivation, but I would like to ask that an appendix be added to the paper showing clearly how the formulæ are obtained, for the sake of those of our members who are out on the "frontiers of Empire" building dams, with perhaps but a few old text-books by them. I think that the data would be of great assistance to them, and the author has all the information at his disposal, so it would not be trespassing too much upon his time.

The author deprecated putting a trench in front of dams. It is presumed that the principal objection to the front trench is that there is, or may be, a tendency to form a vertical crack extending upwards from the back of the trench.

The author stated that dams in the tropics, or near the tropics, with downstream faces towards the Equator or facing west or east may with advantage be provided with temperature skins to a depth depending upon the extent to which daily or annual changes in temperature deprive the outer shell of the face of its value as material resisting compressive stress. It is presumed that the extra skin should be on the downstream face——

Mr. RYVES :—Downstream face, I say.

Mr. ETCHELLS :—The point is an important one, and it is necessary to discover under what conditions we are to use the temperature skins. While for the moment, it appears as though we are dealing with some subject outside reinforced concrete, the questions to be raised have a very direct and practical bearing on the actual construction of the dam. It is really important, so that the engineers I have spoken of, that are far away, may know when they should and when they should not put on the temperature skins.

Rather than enter upon a long astronomical disquisition on the aspect of the sun in various latitudes, I submit herewith two diagrams showing that it may be necessary to construct temperature skins on dams which have an aspect contrary to that indicated by the author, in addition to those cases which the author has specially mentioned.

In regard to Garrett's design, there is one point in Garrett's design which I should like to draw your attention to, because it is not always attended to in the arched dams. You will notice that Garrett has his arches at the arc of a circle. That, I should think,

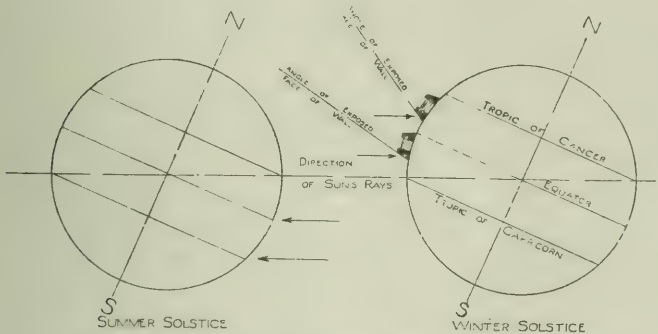


Diagram showing that the necessity for a temperature skin exists whether the downstream face is towards the Equator or not

would be quite correct, because the pressure of the water is radial in every direction, and if you could complete the arch you would get a circle of radial pressures, and Garrett's design on that point is certainly a good one.

I would like to ask the author for information as to the horizontal reactions. In the case of the very high dams, often considerations come in that may be fairly negligible in a little retaining wall round a building. The question is as to whether the whole of the horizontal reaction is assumed to be taken up by friction or whether partly by friction under the base and partly by shear of the toe. In other words, does the author, in his practice in very high dams, take the question of friction along the bottom as being the

sole determining factor, or does he take the shear stress across the toe as being auxiliary and not supplementary? He takes a combination of both, I presume.

MR. RYVES :—A combination in the middle ; a shear at the junction.

MR. ETCHELLS :—So you consider the total reaction made up of two factors—shear and friction.

MR. RYVES :—Yes.

MR. ETCHELLS :—The proportions must be difficult to fix. But I do not raise that question now, it is too complex ; but I might add one point, however, in which a question of practical engineering came in *versus* theory. Theory is perhaps as near as we can get to the truth, but theorists, as a rule, often take what they consider the chiefest factors. But the chiefest factors in their opinion are not necessarily the chiefest factors in fact. I heard of an American engineer who, prior to the San Francisco earthquake, had one of his assistants calculating the resistance of a dam in which the pressures and stresses were set out very nicely and prettily to the last decimal. The design was like this—

The chief engineer examined it and remarked : " Yes, that is a very nice design ; we will turn it this way up." Thus !—

The dam was built in that position and it withstood the earthquake, which the theorist had not allowed for.

MR. MORGAN E. YEATMAN, M.A., M.Am.Soc. C.E., M.C.I. :—I do not know that I have much to say, Mr. Chairman. I might say, with reference to the new Croton Dam and the question that Mr. Marsh raised, that I think Mr. Ryves is right, that the figures sometimes given for the height of the dam are misleading. I forget what the actual maximum figure is—something like 280 ft., but that is really from the bottom of some excavations in the foundation which were made to get down to sound rock, and there is no section of the dam of the proper outline of 280 ft. high : 280 ft., I think, is the height from the top of the dam to the bottom of the lowest point of the foundation, but these foundations are irregular holes dug over a base of a very wide extent in order to get down to sound rock. The facts are perfectly irrefutable that that is the greatest height of the dam, but there is no vertical section of the full width of base corresponding to this height.

I did not quite understand the lay out of all these parallel sections in Fig. 1 or how their thickness is regulated. The width of each section on the face of the dam naturally increases down towards the bottom, as the pressure increases ; but when you run down along the lines drawn there from the face down to the bottom, does each section remain of the same width, or does it gradually thicken out down to the bottom ?

MR. RYVES :—It increases to the middle, and after the middle it remains stationary.

MR. YEATMAN :—From the highest point of the section it seems to me to be drawn as of the same width all the way down. But take the middle of the face ; it widens from the water-face down, does it not ?

MR. RYVES :—Yes.

MR. S. BYLANDER, M.C.I. :—I did not intend to speak, only one point that very often is forgotten in considering the right theory to apply in connection with a dam is this, that many assume a dam to stand on rock which is not elastic and which will not give under pressure to any considerable extent. It is, of course, not the case. The rock will give or change its thickness in a similar way as a structure subjected to stress will. It can, as the previous speaker has mentioned, be demonstrated very nicely and very simply by making a section of a dam in jelly and subjecting one side to pressure. Then it can easily be seen how the jelly is deformed and shows the intensity of the pressure. Suppose you take a section and draw a horizontal and vertical line, thus producing squares, then producing a pressure on one side of the dam, the squares would be deformed, and the more they are deformed the greater the pressure. There must be a difference in pressure at different layers, I should say.

MONS. MAURICE BÉHAR, M.C.I. :—The only thing I can say with regard to the statement of Mr. Ryves, that reinforced concrete is not suitable for high dams, is that I do not see any reason for not using reinforced concrete. I think high dams in reinforced concrete can be executed, and as far as the cost is concerned they would be very much cheaper. This is especially true when we consider the large quantity of materials required for masonry or earth dams.

Another reason in favour of reinforced concrete concerns the question of excavations. By the distance between two buttresses the excavations would be reduced considerably in high dams.

I cannot now give correct data concerning this matter, but it seems to me that reinforced concrete

could be adopted, in certain cases, for the purpose of high dams.

Personally, I have read of works of that kind in masonry. There is one, for instance, called "Barrage de Furens," near St. Etienne, in France, built by Mr. Hirsch, Professor at the Ponts et Chaussées School, in which the masonry works partly in tension.

The figures of this barrage are not exactly in my mind, but I think the base is 7 metres or 8 metres for a height of 50 metres or 60 metres of water. The dam is more than thirty-five years old.

In reinforced concrete the thickness of walls would be reduced considerably, compared to the above, except the buttresses, which would remain very wide; but the total amount of materials in the work would be reduced considerably, compared to those in masonry or earth.

MR. A. ALBAN H. SCOTT, M.S.A., M.C.I.:— Simply as an innocent architect, ignorant of these great engineering works, perhaps I might intrude on the discussion and ask whether on all these interesting questions some lessons have not been learned from what I may call the rather considerable number of failures which have happened in dams. There is one, I think comparatively recent, in America, a fair-sized dam, which is a very bad failure, and surely from that some of these questions which have been argued this evening can more or less be determined from practical experience rather than upon theory.

There is just one other question on Figure 10. It seems to be rather curious, that arrangement. It appears that there are no means taken for preventing the water from getting underneath the upstream side of the dam, and if that is so does not that have any weakening effect or any effect on the stress taken up by the dam, by giving practically a free passage of water to probably two-thirds the width of the base, and with that water there, does not that reduce all questions of relying upon friction?

With regard to reinforced concrete dams, the author simply makes the statement that they cannot be done to a great height. He does not give the reasons, and I think with Mons. Béhar there cannot be any reason, if you can build in other forms of concrete to any height, why you cannot build in reinforced concrete.

In a place like India the question of variations of temperature and the consequent contraction and expansion of the dam might entirely throw out all one's calculations for portions of it. But that, after all, is perhaps only a question of the thickness of the protection to the steel used for the reinforcement. But from an engineering calculating point of view I do not see why there should be any difficulty.

I am sorry to intrude on this discussion, Mr. Chairman. I am not competent in any way to talk about dams, but these few points were of special interest to me.

Mr. W. PERKINS, M.C.I., District Surveyor for Holborn :—The author has stated that he thinks it is impossible to construct a dam in that form with reinforced concrete, and other speakers have dealt with that point. May I ask if it would be possible to construct a dam of that section in a compound way by using masonry for one portion of it, the buttresses, and by using reinforced concrete as a slab, instead of the arches?

Mr. R. DUDLEY, Assoc.M.Inst.C.E. :—There is one question, sir, I should very much like the author to give us some information about, because his paper is so extremely interesting, especially to me as an Indian engineer. He has spoken of the question of treating the substratum on which the dam rests, and he has treated it as if it was known before he designed the dam—as if the substratum was *exactly* known. In a dam that I was connected with in South Wales we made some beautiful calculations, but when we came to excavate the rock we struck an old coal level, and on another dam that I know of a vein of sand going down about 50 ft. in one place was met, so that any calculations you make based on the assumption that you are going to meet rock and strata, which you may set out as you have shown in Fig. 10, may require much modification when the exact nature of the ground is known and non-bonding is difficult.

I have no printed paper by me, and I am rather at a loss in quoting. I think Mr. Ryves was going to treat the middle-third in one way and the upstream third in another, and the downstream third in another, tension and bonding, and not bonding.

MR. RYVES :—Gradually increasing bonding from the front to the back.

MR. DUDLEY :—Well, if you strike a vein of sand, you have to go down with your concrete or your puddled trench. It would be very interesting if the author would kindly explain how his design would be modified to meet such a state of things.

MR. ETCHELLS :—A reinforced slab across the coal-hole would fill the bill, I think. (Laughter.)

THE CHAIRMAN (MR. E. P. WELLS) :—In looking at the various designs, and especially the author's thrust buttress dam, I do not see why reinforced concrete should not answer with the heights that he has given, and also show a very considerable saving in cost. The suggestion that I should like to make is this : that for a height of 100 ft. up, instead of his thrust buttresses being at centres of 60 ft., he should place them at 30-ft. centres so that the arches on the face, to resist the maximum water pressure, would be 30-ft. span, as against 60 ft., and so only have a quarter of the horizontal thrust. It then becomes a question as to whether the extra amount of material that you will have to put into your buttresses would cost more than the extra material put into your arch for a 60-ft. span as against a 30-ft. span.

One practical suggestion I should like to make is that if the author constructs a dam of that size, instead of having a perfectly plain surface on the face, that it should all be in a series of steps of about 18 in. The reason that I suggest this is, that in erecting you can carry the whole of your scaffolding along with perfectly level bottoms, and it can be lifted up from the bottom to the top, and the same scaffolding used throughout the entire length ; whereas if you have a plain surface that anything can slide upon, it becomes a most difficult matter for construction, and very much more costly. That is one of the points which struck me, and which I think would make a great difference in reducing the cost, and it would not be more difficult to make the joints tight than it would by having the joints at right angles to the face.

With regard to the question of reinforced concrete

I do not see any reason why it should not be done in that material. In fact, the stresses that the author shows on the stonework did not amount to more than, I think, 12 tons or 14 tons a foot on the base.

MR. RYVES :—Ten tons a foot on the base.

THE CHAIRMAN (Mr. E. P. WELLS) :—Well, it is a very, very poor plain concrete that will not resist the 10 tons a foot, and I think even the London County Council permit 12, so that if you use reinforced concrete the cost could very considerably be reduced. In fact, I think that if the author were to go into the matter carefully, even with the increased cost of cement in India, he would find the maximum total weight that he would have in his foundations, if in reinforced concrete work, would possibly not exceed 5 tons to 6 tons per square foot, especially when you can take into account that if he places his buttresses at centres of about 60 ft., and inverts the arches in between the same, he has got an enormous area over which to distribute his load. There is one question raised also about excavation. If it is a question of cost, of going down to obtain a very hard bottom, then it means a very considerable saving.

After these few remarks I now propose a most hearty vote of thanks to the author for the paper which he has read, and I will now call upon him to reply to the various speakers. (Applause.)

MR. RYVES :—The various points that have been put forward show that the paper has dropped on matters that are of interest. I think I might say first of all, in reply to the remarks of several gentlemen, that I have not made calculations to show that a reinforced concrete dam up to 180 ft. high, on the principle of my thrust buttress dam, could or could not be built. I said that reinforced concrete could not be used economically for very large dams, and I have no doubt whatever that there is a limit in height under ordinary circumstances beyond which the reinforced concrete dam becomes too expensive, simply because the materials are too expensive. Portland cement is an expensive material, and the very poor stuff that would stand 10 tons per square foot may be very cheap stuff.

Under different circumstances, of course, it is possible that a reinforced concrete dam could be built to a great height, and such a case as that of the Furens dam, which is 183 ft. in height and is built to a radius of only 823 ft., and is in a narrow gorge, points that way. A dam of that sort might very well be built of reinforced concrete, but my paper was really confined to the consideration of the case of a dam across a wide valley. When you want an enormous quantity of materials, you must spread out your loads upon a large base; and you do not want to concentrate your loads. If you have a material which will carry easily 20 tons to the square foot, and by means of that material you transmit loads down to the ground and then have to spread it all out again to bring it down to a few tons per square foot, that is an expensive process. It can very readily be done for security and with safety in calculation, but it is an expensive process.

It seems to me that the thrust buttress type of dam hits the happy mean in collecting the water loads and concentrating them only to a small extent, so that it only has to spread them out again to a small extent when it reaches the rock, or not, perhaps, spread them out at all.

I will now take the questions as they came in order. Mr. Marsh asked whether the buttress of the parallel slice dam is intended to be built with vertical sides, so that the arches are all the same span the whole way up—the arches or spans, whatever they might be. That is so. The point in connection with that type is that you avoid going away from the ordinary theory altogether. If the theory will hold in the case of a buttress with the sides exposed—vertical sides—you do not want to tempt Providence any further by battering the sides or by altering the shape in any way; you want to treat it as if it were a portion of an ordinary mass gravity dam.

About the New Croton Dam, I think that the correct height is 238 ft. for anything like a considerable section, and, as another speaker said, if there is a greater depth it is only a hole filled up with masonry. As a matter of fact, all the base of the dam is nothing more than a hole filled up with masonry. They made

a big hole in the world, they filled it with concrete, and on the top of that they built a dam 150 ft. high. Then they said they had got a dam 238 ft. high. If you are to make a solid hole in the world at a greater depth than that, fill it in with concrete and build on that, it is not the same thing as a free dam in free air. There is all the difference between an aeroplane running on the ground and an aeroplane in free air. You cannot fall from the one and you can fall from the other.

Such a dam may topple over at any plane in its free height ; it cannot topple over at its base, so that the question of security does not come in at all the same way.

With regard to my own opinion about $p \sec^2 \phi$, I do not want to bear the burden of that opinion. It is everybody's business, and the mathematicians have developed the theory. If near a surface of masonry you have a vertical pressure, p, then at the surface of the masonry you have a pressure $p \sec^2 \phi$. The vertical component of the pressure at the downstream face of the dam is probably much less than p—that is, you do not adopt the straight line of distribution, the sloping straight-line curve of pressures on the base. If that straight-line curve *is* correct there is tension under the dam. Then as to the reinforced concrete, I have a note here that the small reinforced concrete dams that have been built are not thrust buttress dams, because they are calculated as gravity dams. I think you will find, those who are interested in the matter, after going into it, that no dam has been designed as a thrust buttress dam. Several dams in America have been designed with some reliance being placed upon the fact that a part of the water load was transmitted to the rock directly, but those dams are designed as gravity dams on the toppling-over theory. Portions of them are not so placed that they transmit water thrust directly to the bottom. You will find, even in the small dams, that those small dams do not quite act as thrust dams. They transmit the lower part of the water load to the rock, but not the upper part of it.

Another of Mr. Marsh's points was with regard to Fig. 11. That drain through the dam is a sluice.

In damming rivers you often have to provide a sluice through the dam, so if you let the water from the lower portion of the face reach that point, the only head of water against the lower part of the face is due to the head up to the level of the sluice. I am not supposing that you cut the drain through there solely for the purpose of draining it. If I did, I should put it well below the surface of the ground, perhaps 20 ft. or so ; but having, as in many cases one has, a sluice in order to keep down the silt, that sluice is a very convenient way of connecting up to the lower part of the face.

With regard to Mr. Marsh's other point, about keeping the "plums" apart, I certainly did contemplate keeping them quite a foot apart.

There are some points raised by Mr. Andrews that I will not go into now. I also had the advantage of having sat at the feet of Professor Karl Pearson, and if I had not I do not know that I should have read this paper. I could show Mr. Andrews, perhaps, some papers which he might look at in connection with the matter, but I could not go into the theory now, as suggested ; I could not go into it very well in connection with this paper, which is a practical paper entirely ; I am taking certain things for granted. If there is any advantage in going thoroughly into the matter in any other way, I am very ready to do it ; I have got any amount of material.

But I would like to say that I worked out the question whether there is tension in the under side of the dam or not, and I went on modifying the straight-line distribution of pressure until I found there was no tension ; but adopting the straight-line theory of distribution of pressures under the dam, I found that there is tension. Instead of working in horizontal layers, the usual way in which you work out the stresses in a mass dam by dividing it into imaginary horizontal layers, I divided it into imaginary vertical layers, and I found that I definitely got strong tension ; I then modified my curve of pressures until I got no tension, and I said, "Let us assume, believe, or hope that is the true curve of pressures."

All the engineers who study the subject evidently believe that the maximum of the curve of pressures

is a little before you get to the toe and not quite at the toe. That is shown in the article I have referred to in *The Engineer*.

Then as regards the bonding into the rock on the upstream side, I do not believe in making a trench at the upstream toe at all, because I think that causes tension. I worked out a number of mathematical examples in the same way, using imaginary vertical strips, and assuming the dam was fixed at the upstream toe and afterwards assuming it was fixed in the upper half, middle half, and towards the downstream end. If you work it out graphically you get, in the first two cases, very severe tension in the under side of the dam, and, when you come to think of it, it is only natural. I made extreme estimates for the sake of getting definite results, but those extreme estimates in an exaggerated form brought out what are actual facts in actual practice.

As to Mr. Etchells's point about the verification of formulæ, I propose to make a summary of some kind, or at any rate to go into the materials I have got, and if anything can be usefully put forward in a simple form I am very ready to do it. Alluding to Figs. 9 and 7, I think some explanation was asked, of how I got this $p \sec^2 \varphi$, and I think I will put that in the same boat as the other points to be gone into, if I can put them in a convenient form for ready reference.

As to shear, whether this is shear or whether it is friction under the dam, I want only friction at the upstream end because I want the dam to move rather than the rock. I think trenching tends to split the rock at the upstream toe, and I want to develop compression as far as possible. The resistance should be as far as possible in the form of shear towards the downstream toe. That is based upon those calculations that I made in which I found tension under various circumstances, but not if you fixed the downstream end. I have got one or two diagrams showing the sun and the different Signs of the Zodiac which I will show to Mr. Etchells. Perhaps he would like to suggest their being put among the further notes.

MR. ETCHELLS :—I do.

MR. RYVES :—Then in reply to the point raised by Mr. Yeatman as to the New Croton dam, that has already been dealt with.

Then as to the thickness of the slabs in the buttress in the thrust buttress dam, Fig. 1, the water load comes upon the slabs at their ends, and as the slabs go down underneath the masonry, which is above them, I go on counting in the component at 45° due to the weight of the masonry above them. So, until you get to the middle line under the apex, the buttresses go on increasing in width ; then, as the load does not increase after that, the width does not alter. The buttresses being parallel to the other face, the load does not increase, so the buttress keeps the same width. It widens out to the middle line and then keeps that width the rest of the way. The weight of the masonry is fully taken into account. And to meet another point I have not taken the vertical component as a matter of any importance, because the bottom of the dam is supposed to be a zig-zag at 45°, so the pressure would only be 45° one way or another ; you would not get any vertical component because you have no horizontal base.

As for building high dams in reinforced concrete, as I say, I have not worked out examples, but my point is that those who think they can be built had better work out the examples. They are much more competent than I am to work out the cost of a very high dam in reinforced concrete, and I think it much better that they should do it and let me criticise them than that I should put forward a possibly weak and inefficient design and have that criticised.

About lessons from failures ; I have studied the recent failures of dams in the United States, and I have not found any useful lessons in them at all except not to do it like that again. We should not have done it like that before. There are no failures in India, I think, of any big important works. They are, at any rate, very rare indeed, and we very seldom have failures in important works in England. The condition of affairs in America is different. Things have to be done comparatively in a hurry. I do not believe these failures teach you anything. I believe one could learn something from a recent

failure of a Spanish dam, but I have not got any particulars of that.

As to what I should do if I came upon a deep crevice in the rock in order to fulfil the conditions of Fig. 10, I would fill up the crevice with masonry and reduce the surface as far as possible to a surface similar to the rock. But if it was near the downstream toe I would bury it right into the dam. If near the upstream toe I would fill it up to the level of the rock as far as possible, but, of course, with a very irregular bottom you cannot evolve any theoretical ideas as to how you are to make your foundations in that case. You take advantage of every surface which is more or less at right angles to your thrust, and use that.

As to the Chairman's point about the buttresses being close together, the buttress at the base is 38 ft. wide in the front, and that means that the span of the arches is small. If you look at Fig. 1 you will see that the thickness of the arch ring does not increase from the top to the bottom in proportion to the head of water above it. That is because the span is getting less and less. I do not think there are any other points that I can usefully go into now, and it is getting rather late.

The meeting then terminated.

[It is hoped to include some further notes on the subject by Mr. Ryves in the next issue of the TRANSACTIONS.]

TWENTY-FIFTH ORDINARY GENERAL MEETING

THURSDAY, APRIL 11, 1912

THE TWENTY-FIFTH ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held in the Lecture Hall at Denison House, 296, Vauxhall Bridge Road, London, S.W., on Thursday, April 11, 1912, at 8 p.m.,

SIR HENRY TANNER, C.B., I.S.O., F.R.I.B.A., F.S.I., etc. (President) in the Chair.

The following were elected members of the Institute :—

MR. HUGH CECIL FORDER, Westminster.
MR. PHILIP LEONARD FRANCIS, Westminster.
MR. HUBERT HAUGHTON, Westminster.
MR. CHARLES BENJAMIN IFE, Westminster.
MR. RICHARD GOULBURN LOVELL, A.R.I.B.A., M.S.A., Eastbourne.
MR. THOMAS DE COURCY MEADE, M.Inst.C.E., F.S.I., etc., City Engineer, Manchester.
MR. EDWARD MEREDITH, Stud.A.R.I.B.A., Llandrindod Wells.
MR. JOSEPH EDWARD MUNDELL, A.R.I.B.A., F.S.I., M.R.San.I., London.
MR. ANTONIO VON OSENBRUGGEN, Westminster.
MR. ALBERT OVENDEN PITT, Westminster.
MR. FRANK RADCLIFFE, Little Royd, Huddersfield.
MR. WALTER CAWTHORNE THORNELEY, Westminster.
MR. BERTIE CARLOSS WHEATCROFT, Westminster.

THE SECRETARY (MR. H. KEMPTON DYSON) announced that the following had been admitted as Students of the Institute :—

MR. EDGAR ALBERT BURKE,
MR. NOEL EDWARD CREASY,
MR. JOSEPH HAROLD DOSWELL,
MR. VICTOR HAIDEN KNIGHT,
MR. PERCIVAL ST. JOHN PARKINSON,
MR. CECIL JACOB PELL,

MR. MARK PITTER,
MR. REUBEN STUBBS, and
MR. THOMAS S. VANDY, all of Westminster.

MR. G. C. WORKMAN then read MR. MAURICE BÉHAR'S paper entitled, "The True Bending Moments of Beams with Various Degrees of Fixity," as follows :—

THE TRUE BENDING MOMENTS OF BEAMS WITH VARIOUS DEGREES OF FIXITY.

By MAURICE BÉHAR, Civil Engineer (Ecole des Ponts et Chaussées).

Although most of the countries in Europe have official regulations for reinforced concrete works, there is no regulation of this kind in Great Britain yet, and architects and engineers have so far been governed by the First and Second Reports of the Royal Institute of British Architects' Joint Committee, or by the usual practice of the various firms of specialist designers.

I understand, however, that Official Regulations are now proposed, and that these will shortly be adopted for reinforced concrete works, not only within the radius of the County of London, but for all such works as come within the scope of Local Government officials, and I fear that if certain principles and formulæ are introduced into these Regulations, concerning which there has recently been a certain amount of controversy, the progress of reinforced concrete may be severely hindered.

The object of this paper is to discuss each of the principles and formulæ which I have mentioned above, and also to show, by means of examples, the excessive increase in the weight of the steel bars in beams and posts in reinforced concrete, due to the application of these methods.

I shall first consider the case of beams. Until now almost all the engineers specialising in reinforced concrete calculate these elements by applying the usual laws of mechanics, or, in other words, the laws governing the strength of materials. Nevertheless, for the main beams and secondary beams fixed at their extremities to other members in reinforced concrete, such as walls, posts, or other beams, the specialist engineers usually admit that a certain amount of fixity takes place at these points of junction, and concerning this it is usual to make certain assumptions.

Some engineers consider that the fixation is partial on the support, and has for its value $\frac{WL}{24}$. In this case they calcu-

late their moment at the middle of the beam, sufficiently strong to resist a bending moment of $\frac{WL}{12}$, which is the corresponding moment to the one stated above.

Other engineers, and we think they are in the majority, consider that the bending moment should be $\frac{WL}{10}$ in the middle of the beam, and in this case they provide at the points of support a section of steel capable of resisting a corresponding moment of $\frac{WL}{40}$.

Again, other specialists consider that reinforced concrete beams extending over several spans must be considered as continuous, and they apply to the calculation of these beams the usual rules governing continuity.

In addition to the three above-mentioned methods of calculating a beam in reinforced concrete fixed upon its two points of support, it is now my intention to consider the method which has been put forward for official sanction, and which would have the effect of stipulating a bending moment of $\frac{WL}{12}$ in the middle of the beam and $-\frac{WL}{12}$ at the points of support.

Of these four methods of calculation, let us consider the question of which one produces the maximum of safety in the construction.

1. Let us assume that the bending moment in the middle is $\frac{WL}{12}$, and that the corresponding moment at the points of support is $\frac{WL}{24}$. It may happen that on account of the continuity of two consecutive beams and the distribution of the loads on the spans, that the moment at the point of support becomes greater than the one provided for. In this case fissures will occur at this point.

Let us now assume by exaggeration that these fissures render the points of support absolutely free. The middle of the beam will then support a bending moment equal to $\frac{WL}{8}$, but as the beam has been calculated for a bending moment in the middle of $\frac{WL}{12}$, the factor of safety will become

$$4 \times \frac{8}{12} = 2{\cdot}666 \text{ instead of } 4.$$

The beam will not collapse on this account, inasmuch as the concrete in the lower part of the beam situated underneath the neutral axis is working in extension, which has not been taken into account in the calculations.

2. Let us now assume that the bending moment in the middle is $\frac{WL}{10}$ and the corresponding moment at the supports is equal to $\frac{WL}{40}$. The method of reasoning is the same as for the above, except that in the case of the transformation of the point of support into a free support the factor of safety becomes

$$4 \times \frac{8}{10} = 3{\cdot}2 \text{ instead of } 4.$$

3. Let us now consider the continuous beams. In this case the moments at the supports are generally greater than $\frac{WL}{12}$.

Concerning the moments in the middle of the spans, they will often be much less than $\frac{WL}{12}$. We must remember, however, that although in structural steelwork it is possible to obtain perfect continuity between two consecutive spans, it is not so with reinforced concrete, where the continuity depends upon the adherence of the concrete to the bars provided in the upper portion of the beam at the points of support.

I am of opinion that the method of constructing consecutive beams in reinforced concrete does not ensure such perfect continuity as that which may be obtained in consecutive metallic girders. If owing to this lack of solidarity between two consecutive spans, or if owing to bad construction the point of support should give way and become transformed into a free support, then the middle of the beam, which may in certain cases have been calculated with a moment less than $\frac{WL}{12}$, will have a factor of safety less than 2·66, and in certain cases even less than 2. It is obvious that the construction in this case becomes endangered, and the danger is all the greater because if one of the beams gives way the others will give way in turn, on account of the fact that the continuity upon which we relied will have disappeared owing to the failure of the first element.

It is for this reason that in steel construction, when there are several continuous spans, it is usual to divide these into a series of portions of three or four consecutive continuous spans, each portion being separated by free supports.

4. If we consider $\frac{WL}{12}$ in the middle and $-\frac{WL}{12}$ at the points of support, this case certainly has the effect of producing a greater safety than those above mentioned. In the middle there is the same drawback as in the first case, but not the one due to continuity. At the supports, however, this case is weaker than the case of continuity, although it has very nearly the same value. On the other hand, the latter method obliges the engineer to provide, as in the case of continuity, in the bottom compressed portion of the beam, and at the points of support, a considerable section of steel, and this section will be all the greater at these two points, on account of the fact that, if this principle is admitted in the Official Regulations, the section of steel required will have to be calculated by applying a stress in the steel equal to fifteen times the stress of the concrete, taken at the axis of the reinforcement employed.

Now, as a matter of fact, a large number of examples of principal beams and secondary beams which I have calculated with $\frac{WL}{12}$ at the supports, have proved to me that the working stress of the steel in compression is always below 8,000 lbs. per sq. in., and that in secondary beams this stress rarely attains 6,000 lbs. per sq. in. The result is that one is often obliged to provide such a considerable number of steel bars, that it is materially impossible to place them in the small compressed area of the concrete, in the bottom of the beam.

A close examination of the four methods of calculation mentioned above has led me to conclude that as far as stability is concerned, the moment of $\frac{WL}{12}$ in the middle and at the supports gives a greater security. $-\frac{WL}{24}$ or $-\frac{WL}{40}$ at the supports and their corresponding values of $\frac{WL}{12}$ or $\frac{WL}{10}$ in the middle would never actually cause the collapse of a beam. The most that could happen in such a case would be, that the floor slab over the beams would show fissures, whereas, if we consider the case of continuity, we

find that this may prove dangerous if the workmanship is bad or the materials unsuitable.

From an economical point of view, the semi-fixation with moments of $-\frac{WL}{24}$ at the support and $\frac{WL}{12}$ at the middle, requires about the same amount of steel as the partial fixation with moments of $-\frac{WL}{40}$ at the supports and $\frac{WL}{10}$ at the middle.

Concerning $-\frac{WL}{12}$ at the supports and $\frac{WL}{12}$ in the middle, when it is possible to actually construct the beam by accommodating the amount of steel required, I have found that these values bring about an increase 40 to 50 per cent. greater than required in the cases of semi or partial fixation mentioned above, and that in certain cases the excess of steel may be as much as 100 per cent.

Concerning the case of continuity, if we are obliged to provide in the lower portion of the beams the necessary section of steel to take up the compression at the points of support, and if we put aside the method which consists of reinforcing this portion by means of spirals, the weight of the bars would be less than that due to $\frac{WL}{12}$ at the supports and in the middle, but the weight of steel would be superior to that produced by the formula of semi or partial fixation.

I understand that for various reasons the method of reinforcing the concrete in the beams by means of spirals would not be considered or authorised in the new Regulations, and it is doubtful whether this particular method could meet the difficulty in an economical manner. If, however, the new Regulations were to allow the use of spirals, to increase the compression of beams, and if it was found that this was the only possible way of solving the difficulty of the compression, then it is obvious that the Regulations would have the effect of favouring, to the exclusion of all others, one particular method only for which a patent has been obtained, thereby creating a monopoly.

It is therefore absolutely necessary that the proposed Official Regulations should not have the effect of obliging engineers to calculate beams fixed at both extremities with a bending moment of $-\frac{WL}{12}$ at the supports and $\frac{WL}{12}$ at the middle, and I sincerely trust that the authorities,

who are at present drafting out new Regulations, will simply stipulate the application of the usual laws of mechanics for the determination of the dimensions of beams in reinforced concrete ; and also hope that the case of semi-fixed beams, which is in no ways empirical, and which is absolutely in conformity with the laws of mechanics, shall be considered and shall find its proper place in the new Rules.

Compression in the Upper Portion of the Beams and in the Middle of the Span.

I understand that it is intended to introduce in the new Rules a clause stipulating that the width b of the slab working in compression together with the beam shall be equal to the smallest of the following values :—

(*a*) To one-third of the effective span of the beam.

(*b*) Or three-quarters of the distance centre to centre between beams.

(*c*) Or six times the thickness of the beam.

(*d*) Or fifteen times the thickness of the slab.

I have found that the cases *c* or *d* are those which will be usually applied, especially for principal beams. It is obvious that owing to this the compression will almost in every case be insufficient at the centre of these beams. As, on the other hand, the upper bars are usually placed 2 in. from the upper surface of the beam, the working stress of the steel will rarely reach 8,000 lbs. per sq. in. We shall therefore be obliged to provide a relatively considerable section of steel in the top portion of the beam, and in certain cases this section might even exceed the section of the steel in tension, unless the Rules authorise engineers to consider the beam in the middle as being practically a steel girder, and in this case the sections at the top and at the bottom would be equal ; but of course the compression of the concrete would have to be neglected.

Now, if we examine a reinforced concrete construction composed of slabs, secondary beams and principal beams (for instance, floors or retaining walls), the construction presents an absolutely monolithic and rigid table, and as the component members are working together, I would suggest that in reality it would be possible to assume that the entire distance between centre to centre of the secondary beams or main beams is working in compression. In other words, that the entire area of the slab could be taken for the resistance in compression of the beams.

The only objection to this method of procedure is that to

the compression of the slab itself considered separately we must add the compression produced by the secondary beams ; that is, if we only consider a slab and secondary beam.

If we consider the principal beams we find that to the compression produced by the latter we must add the compression due to the secondary beam. It is possible that the resultant of these two forces may produce a compressive stress superior to 600 lbs. per sq. in. especially in the case where the compression of the slab is working with the secondary beam, inasmuch as the slab itself is usually calculated for a stress of 600 lbs. at the extreme compressed fibre, but when the slab is working with the principal beam it is only influenced by the compression of the secondary beam, and as in reality the entire table or slab is working in the direction of the secondary beams as well as in the direction of the principal beams, the result is that the rates of compression at the extreme compressed fibre are comparatively low, and the resultant rarely attains 600 lbs. per sq. in., except in the case where the sectional area of the concrete being insufficient, the designer has been obliged to introduce a certain section of steel in compression.

It follows from the above method of reasoning that it would be possible to retain the clauses *a*, *b*, and *d* for the secondary beams, but that it would be advisable to suppress the clause *c*, which I consider is unnecessary as applied to secondary beams, and I am of opinion that clauses *a* and *b* only should remain for the principal beams.

It is perhaps for the reason mentioned above that the French Regulations for reinforced concrete stipulate that three-quarters only of the slab application must be taken for the compressive resistance of secondary beams, or one-third of the span of the beam, whichever is the smallest ; but it is to be noticed that these Rules have not prescribed anything concerning the principal beams, so that in France engineers are free to take the entire width of the slab for the compressive resistance of the principal beams.

I wish to make it clear that I do not actually advise that this should be done, but that clauses *a* and *b* should subsist for the calculation of the compressive resistance of principal beams.

Reinforced Concrete Lintels or Beams without Slabs.

I am under the impression that the proposed Regulations have not put forward any rules to deal with this case. If, therefore, we apply to these beams the formulæ applicable to

rectangular beams, we would have to take for the stress of the steel in compression fifteen times the value of the stress of the concrete at the centre of gravity of the section of the compressed bars, namely, about 8,000 lbs. per sq. in. A reinforced concrete lintel will therefore have a weight of steel often superior to that of a steel girder or joist, and on this account there would be no advantage in future in adopting reinforced concrete for this kind of work.

I think it advisable to draw your attention to this matter, which is of great importance, and I trust that the authorities will see their way to investigate this particular case, and to either authorise engineers to design these lintels or rectangular beams without slabs as steel beams, namely, to allow the section of the steel to be calculated at the same rate in tension and compression, the compressive resistance of the concrete being neglected.

Posts or Pillars in Reinforced Concrete.

Concerning the calculations of posts or pillars, I take it that the formula which is intended to be adopted will be—

$$P = c(A + (m - 1)A_s),$$

in which c represents the working stress of the concrete in direct compression, A the effective area of the pillar—that is to say, the section of the pillar after deducting the area of concrete situated between the external faces of the pillar and the vertical bars, A_s being the section of the vertical bars and m equal to 15.

Although this formula may be applied to the case in which the transverse reinforcement is taken into account, and where the diameter of the transverse reinforcement and the spacing of same per foot run would lead us to take for c much higher values than 600 lbs. per sq. in., I fail to see why this formula should be applied to ordinary pillars, seeing that for purely constructional reasons only transverse reinforcement has been introduced for the binding together of the principal bars during the concreting operation, and in this case it would appear to me that the total section of the concrete should be taken into account, which has been, and is, the usual practice of most of the experienced designers in reinforced concrete.

If an additional stipulation is considered necessary for further safety, I would suggest that this should take the form of reducing the rate of 600 lbs. per sq. in. of the concrete in compression, in conformity with Rankine's formula.

In order to clearly demonstrate the consequences of the application of some of the formulæ and proposed Regulations above mentioned, I have studied a floor in reinforced concrete resting upon beams and posts, also in the same material, and to this work I have applied strictly the conditions which would be enforced for the verification of such a scheme by the architect or engineer who would have to apply them.

FIG 1

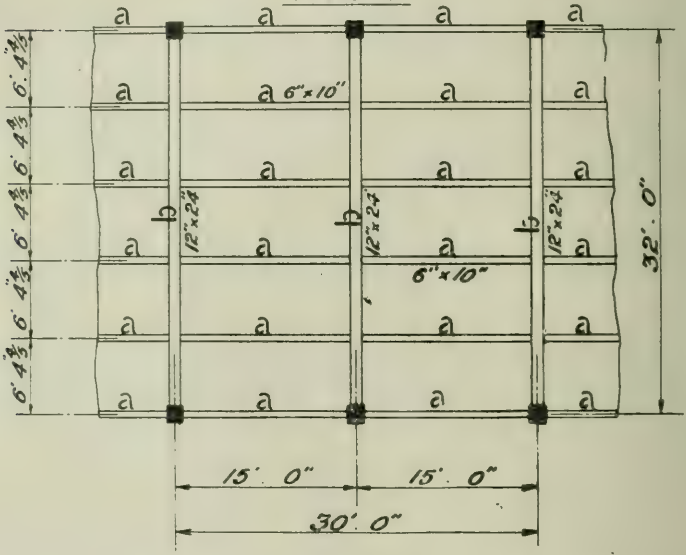


Fig. 1 shows a floor which is to carry a superload of $1\frac{1}{2}$ cwts. per sq. ft., the span centre to centre of the slab being 6·40 ft., the span of the secondary beams being 15 ft., and that of the principal beams 32 ft.

Slab.—Span 6·40 ft.; thickness, 4 in.; rendering, 1 in.

Superload	168 lbs.
Dead load	63 ,,
Total per sq. ft. ...	231 lbs.

$$B_e = B_c = \frac{231 \times 6{\cdot}4^2}{12} = 788 \text{ ft. lbs.} = 9456 \text{ in. lbs.}$$

I have provided for the resistance to this bending moment, and for a width of slab of 1 ft. 0·22 sq. in. of steel in tension.

Verification of the Slab.

The position of the neutral axis is given by the equation :

$$n = (\sqrt{m^2r^2 + 2\,mr} - mr)\,d$$

$$m = 15 : r = \frac{A_t}{b_d} = \frac{0{\cdot}22}{12 \times 3} = 0{\cdot}0061$$

$$n = (\sqrt{225 \times 0{\cdot}0061^2 + 30 \times 0.0061} - 15 \times 0{\cdot}0061)3 = 1{\cdot}0377''$$

The lever arm of the bending couple is given by the formula—

$$a = d - \frac{n}{3} = 3'' - \frac{1{\cdot}0377}{3} = 2{\cdot}6545''$$

The tensile resistance moment is given by the formula—

$$R_t = tA_t a = 17{,}000 \times 0{\cdot}22 \times 2{\cdot}6545 = 9928 \text{ in. lbs.}$$

The compressive resistance moment is given by the formula—

$$R_c = \frac{c}{2}\,bna = 300 \times 12 \times 1{\cdot}0377 \times 2{\cdot}6545 = 9916 \text{ in. lbs.}$$

The two moments of resistance R_c and R_t being greater than the moment due to external forces, the slab is therefore under good conditions of stability.

Secondary beam a.—Span, 15 ft. ; scantlings, 6 in. × 10 in.

This beam supports, per foot run, a load equal to—

Slab and superload 6·4′ × 231	= 1478
Dead load	= 63
Total	= 1541 lbs.

$$B_t = B_c = \frac{1541 \times 15^2}{12} = 28{,}894 \text{ ft. lbs.} = 346{,}728 \text{ in. lbs.}$$

I have provided to resist this moment—

In the middle of the beam in tension ...	2·092 sq. in.
At the points of support in tension ...	2·092 ,,
At the points of support in compression ...	7·42 ,,

I have not provided steel in compression at the upper portion of the beam in the middle, because the concrete of the slab is sufficient to absorb the effort of compression.

1. *Verification of the Resistance at the Middle of the Span.*—The neutral axis being situated inside the slab, the position of the neutral axis is given by the formula—

$$n = (\sqrt{m^2r^2 + 2mr} - mr)d$$
$$m = 15 \qquad d = 10'' + 4'' - 2\tfrac{1}{2}'' = 11\tfrac{1}{2}''.$$

The width of slab b working in compression at the same time as the beam is given by the smallest of the following quantities :—

$$b = 0{\cdot}75 \times 6{\cdot}4' \times 12'' = 57{\cdot}6''$$
$$b = \frac{15' \times 12}{3} = 60''$$
$$b = 4'' \times 15 = 60''$$
$$b = 6 \times 6'' = 36''.$$

I have chosen 36″.

$$r = \frac{A_t}{bd} = \frac{2{\cdot}c92}{36 \times 11{\cdot}5} = 0{\cdot}00505.$$

Substituting in the above equation we have—

$$n = (\sqrt{225 \times 0{\cdot}00505^2 + 30 \times 0{\cdot}00505} - 15 \times 0{\cdot}00505)\,11{\cdot}5$$
$$n = 3{\cdot}683''.$$

The lever arm of the bending couple is therefore—

$$a = d - \frac{n}{3} = 11{\cdot}5 - \frac{3{\cdot}683}{3} = 10{\cdot}273''.$$

The compressive resistance moment is equal to—

$$R_c = \frac{c}{2}bna = 300 \times 36 \times 3{\cdot}683 \times 10{\cdot}273 = 408{,}623 \text{ in. lbs.}$$

The tensile resistance moment is equal to—

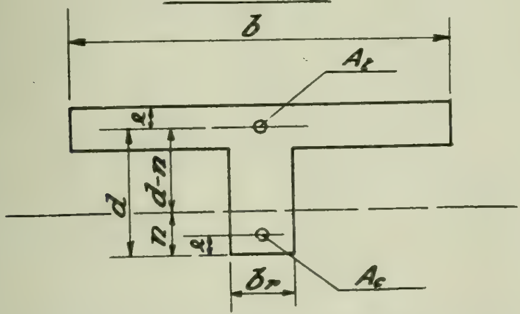
$$R_t = tA_ta = 17{,}000 \times 2{\cdot}092 \times 10{\cdot}273 = 365{,}349 \text{ in. lbs.}$$

The two moments of resistance being greater than the moment due to external forces at the middle of the span, the beam is therefore in good conditions of stability.

2. *Verification of the Resistance at the Point of Support.*—The Second Report of the R.I.B.A. does not give any formulæ for the determination of the position of the neutral axis in a reinforced concrete beam when, the compression of the concrete being insufficient, a certain section of steel is required in the compressed portion of the beam, and I understand that the proposed Official Regulations do not provide any formulæ for this particular case.

In order to verify the support, I have found it necessary to establish this formula by making use of the same theory by means of which the position of the neutral axis is established, when the compression of the slab is sufficient.

FIG. 2



Let us assume that the moment of the extended section in relation to the neutral axis is equal to the moment of the compressed section also in relation to the neutral axis. We then have (Fig. 2)—

$$mA_t(d - n) = mA_c(n - a) + b_r n \times \frac{n}{2},$$

or—

$$b_r n^2 + 2m(A_c + A_t) - 2m(A_c a + A_t d) = 0,$$

hence we have—

$$(1)\ n = \frac{- m(A_c + A_t) + \sqrt{m^2(A_c + A_t)^2 + 2b_r m(A_c a + A_t d)}}{b_r}$$

If we neglect to take into account the small rectangle of the compressed concrete $b_r n$, we can find the position of the neutral axis by the following equation :—

$$mA_t(d - n) = mA_c(n - a),$$

or—

$$n(A_c + A_t) = A_c a + A_t d.$$

$$(2) \quad n = \frac{A_c a + A_t d}{A_c + A_t}.$$

In a general sense, with the exception of beams of considerable span where the rectangle *bn* is comparatively important, the results given by the formulæ (1) and (2) are almost identical.

The formula (2) applied in the case which concerns us would give—

$$n = \frac{7{\cdot}42 \times 2'' + 2{\cdot}092 \times 12''}{7{\cdot}42 + 2{\cdot}092} = 4{\cdot}20''$$

The formula (1) would have given $n = 3{\cdot}90''$.

As the neutral axis comes within $4{\cdot}20''$ of the soffit of the beam, it follows that the working stress of the compressed bars placed at $2''$ from this soffit, is—

$$15 \times 300 = 4500 \text{ lbs. per sq. in.}$$

The lever arm of the bending couple at the point of support is—

$$a = 12'' - \frac{4{\cdot}20}{3} = 10{\cdot}60''.$$

The compressive resistance moment will then be—

$$R_c = 7{\cdot}42 \times 4500 \times 10{\cdot}60 = 353{,}934 \text{ in. lbs.}$$

The tensile resistance moment will then be—

$$R_t = 2{\cdot}092 \times 17{,}000 \times 10{\cdot}60 = 376{,}978 \text{ in. lbs.}$$

These two moments being greater than the moment due to external forces, $B_c = 346{,}728$ in. lbs., it will be seen that the beam is under good conditions of stability.

I would simply draw attention to the fact that by having to apply $\frac{WL}{12}$ at the supports we are led to provide in the compressed portion of the beam a section of steel equal to—

$$\frac{7{\cdot}42}{2{\cdot}092} = 3{\cdot}54$$

or, in other words, over three and a half times as much steel

at the lower portion of the point of support as the section which we have at the top.

If we had taken into account the small rectangle of compressed concrete, this section of steel might have been slightly reduced, but as a matter of fact in the case of secondary beams it will be found that the section of steel required in the bottom portion of the beam at the point of support will always be at least equal to three times the section of the bars in tension.

From a practical standpoint it appears to me difficult, if not impossible, to find a means of placing these bars in the section of concrete of which we would dispose, especially if certain restrictions have to be observed concerning the space to be left between the various bars.

In the case which I have taken as an example the concrete has a section equal to—

$$6 \times 4{\cdot}2 = 25{\cdot}20 \text{ sq. in.},$$

and in this area we have to accommodate 7·42 sq. in. of steel.

Assuming that we choose 5 bars $1\frac{3}{8}$ in. it is obvious that even these comparatively large bars will not be properly encased by concrete.

Principal beam.—Span, 32 ft. Scantlings, 12 in. × 24 in.

Loads per foot run :

Slab, 15 ft. × 231 ft.	=	3,465
Secondary beams $\frac{4 \times 14 \times 63}{32}$	=	110
Dead weight	=	300
		3,875 lbs.

$$B_c = B_c = \frac{3{,}875}{12} \times 32^2 = 330{,}667 \text{ ft. lbs.} = 3{,}968{,}004 \text{ in. lbs.}$$

I have provided to resist this moment—

In the middle of the beam in tension, 10·05 sq. in.
In the middle of the beam in compression, 9·74 sq. in.
At the points of support in tension, 10·05 sq. in.
At the points of support in compression, 22 sq. in.

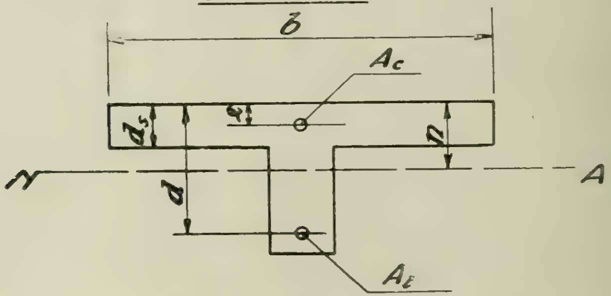
1. *Verification of the Beam at the Middle of the Span :—*

Position of the Neutral Axis.—As we have steel in compression, the formula—

$$n = \frac{s^2 + 2mr}{2(s_i + mr)}$$

of the Second Report of the R.I.B.A. is not applicable. I shall therefore establish a formula which may be applied to this case, as I have already done for the support of the secondary beam.

FIG. 3



Let us assume that the neutral axis falls below the slab. The moments of the extended and compressed sections in relation to the neutral axis will give us the following formulæ (Fig. 3.) :—

$$mA_t(d - n) = mA_c(n - a) + bd_s\left(n - \frac{d_s}{2}\right)$$

or else—

$$n(bd_s + mA_c + mA_t) = \frac{bd_s^2}{2} mA_c a + mA_t d$$

hence—

$$n = \frac{m(A_c a + A_t d) + \frac{bd_s^2}{2}}{m(A_c + A_t + bds}$$

$$d = 24'' + 4'' - 2\tfrac{1}{2}'' = 25{\cdot}5''$$

$$b = 0{\cdot}75 \times 15' \times 12 = 135''$$

or—

$$b = \frac{32' \times 12}{3} = 128''$$

or—

$$b = 15 \times 4'' = 60$$

or—

$$b = 6 \times 12'' = 72$$

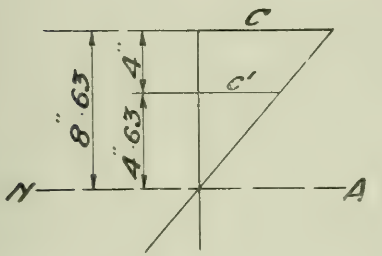
I have taken $b = 60''$.

$$n = \frac{15\,(9{\cdot}74 \times 2'' + 10{\cdot}05 \times 25{\cdot}5) + \dfrac{60 \times 4^2}{2}}{15\,(9{\cdot}74 + 10{\cdot}05) + 60 \times 4} = 8{\cdot}6''$$

Arm of resistance moment :—

$$a = d - \frac{n}{3} = 25{\cdot}5 - \frac{8{\cdot}6}{3} = 22{\cdot}63''$$

FIG. 4



Average compressive stress (Fig. 4): —

$$\frac{c}{c'} = \frac{8{\cdot}63}{4{\cdot}63}$$

$$c' = \frac{4{\cdot}63 \times c}{8{\cdot}63}$$

$$c' = \frac{4{\cdot}63 \times 600}{8{\cdot}63} = 322 \text{ lbs.}$$

$$\frac{c + c'}{2} = \frac{600 + 322}{2} = 461 \text{ lbs.}$$

Compressive resistance moment :—

$$R_c = a\,\frac{c + c'}{2}\,(bd_s + mA_c)$$

$$R = 22{\cdot}63 \times 461\,(60 \times 4 + 15 \times 9{\cdot}74) = 4{,}025{,}874 \text{ in. lbs.}$$

Tensile resistance moment :

$$R_t = tA_t a = 17{,}000 \times 10{\cdot}05 \times 22{\cdot}63 = 3{,}866{,}335 \text{ in. lbs.}$$

The moment of resistance to the compression is greater than the moment of the external forces 3,968,004 in. lbs.

Concerning the moment of resistance to extension, this is less than 101,669 in. lbs., which is the moment due to external forces. This shows, therefore, that the steel in tension is slightly insufficient. We should therefore have to increase it by about—

$$\frac{101{,}669}{17{,}000 \times 22{\cdot}63} = 0{\cdot}28 \text{ sq. in .}$$

2. *Verification of the Beam at the Points of Support :—*

The position of the neutral axis is given, as in the case of the secondary beam, by the formula No. (2)—

$$n = \frac{A_c a + A_t d}{A_c + A_t}.$$

$$n = \frac{22 \times 2'' + 10{\cdot}05 \times 26''}{22 + 10{\cdot}05} = 10{\cdot}16''$$

If we apply formula No. (1), which is more accurate, we find :—

$$n = \frac{-m(A_c + A_t)\ \sqrt{m^2(A_c + A_t)^2 + 2b_r m(A_c a + A_t d)}}{b_r}$$

$$n = \frac{-15 \times 32{\cdot}05 + \sqrt{225 \times 32{\cdot}05^2 + 30 \times 12 \times (22 \times 2 + 10{\cdot}05 \times 26)}}{12}$$

$$n = \frac{-480{\cdot}75 + 582{\cdot}30}{12} = 8{\cdot}46''.$$

The lever arm of the bending couple is therefore—

$$a = d - \frac{n}{3} = 26'' - \frac{8{\cdot}46}{3} = 23{\cdot}18''$$

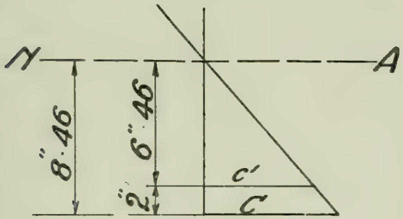
The average compression of the concrete of the beam is $\frac{600}{2} = 300$ lbs. per sq. in. Concerning the compression of the steel, if we admit that the centre of gravity of this section is at 2 in. of the soffit of the beam, which is a

good average condition for the construction, we would have (Fig. 5) :—

$$\frac{c}{c'} = \frac{8 \cdot 46}{6 \cdot 46}$$

$$c' = \frac{6 \cdot 46c}{8 \cdot 46} = \frac{6 \cdot 46 \times 600}{8 \cdot 46} = 459 \text{ lbs.}$$

FIG. 5



The compressive resistance moment is—

$$R = (b n \times \frac{c}{2} + mA_c c')a$$

$$R_c = (12 \times 8 \cdot 46 \times 300 + 15 \times 22 \times 459)23 \cdot 18 = 4{,}217{,}044 \text{ in. lbs.}$$

This moment of resistance exceeds the moment due to external forces by—

$$4{,}217{,}044 - 4{,}025{,}874 = 191{,}170 \text{ in. lbs.,}$$

but, on the other hand, the section of the concrete in compression has been taken into account in the calculation of R_c without deducting the 22 sq. in. occupied by the steel bars.

We must therefore deduct from R_c the following :—

$$22 \times 300 \times 23 \cdot 18 = 152{,}988 \text{ in. lbs.}$$

We see, therefore, that the 22 square inches of steel are absolutely required at each support of the beam in compression, and that this is due to the moment of $\frac{WL}{12}$ at these points of support. As in the case of the secondary

beam, I am of opinion that this section of steel is excessive, and also that it is difficult to see how it is possible to properly embed this section of steel bars, when the total sectional area of the compressed portion of the beam is—

$$12 \times 8{\cdot}46 = 101 \text{ sq. in.}$$

I would also draw your attention to the fact that the abovementioned results are all favourable to the engineer who has prepared the scheme, and might not strictly be in accordance with the requirements of a controller. As I have taken $a = 2''$, whereas I ought to have taken this as equal at least to $4''$, on account of the considerable section of the steel, and with $a = 4''$, it is obvious that we should obtain a section of steel in compression much greater than the one above mentioned.

I would further draw your attention to the fact that in this case again a considerable section of steel, namely 9·74 sq. in., has been rendered necessary in the upper portion of the beam, and in its middle. If, instead of taking for $b = 60''$, which corresponds to 15 times the thickness of the slab, I had taken $128''$, namely, the third of the span, the compression of the concrete would have been sufficient, and this amount of steel would have been economised, as in my opinion there is no danger in taking for a principal beam in reinforced concrete the smallest of the two quantities a and b for the width of the slab in compression, as mentioned already at the beginning of my lecture.

Posts. Scantlings 15 in. × 15 in. Height 12 ft.

The loads to be supported by the posts are as follows:—

Slab and superload $32' \times 15' \times 231$	=	110,800 lbs.
Secondary beams $5' \times 14' \times 63$	=	4,410 „
Principal beam $31' \times 300$	=	9,300 „
Dead Weight $12' \times 234$	=	2,808 „
Total	=	127,318 lbs.

The post is reinforced by means of 4 bars $1''$ diameter = 3·14 sq. in., and the bars are held together by means of spirals or hoops $\frac{3}{16}''$ diameter, not taking into account, however, the calculation of the resistance. Under these conditions the post is capable of supporting, according to the proposed official formulæ—

$$P = c(A + (m - 1)A_v)$$

$$c = 600 \text{ lbs.} \quad A = (15'' - 2'')(15'' - 2'') = 169 \text{ sq. in.}$$

$$m = 15. \quad A_v = 4 \times 0{\cdot}785 = 3{\cdot}140 \text{ sq. in.}$$

$$P = 600\,(169 + 14 \times 3{\cdot}14) = 127{,}776 \text{ lbs.}$$

The post is therefore under good conditions of stability.

It will be noticed, however, that the proposed Rules have obliged me to take a larger post than required owing to the fact that the effective area between the bars is only allowed. The usual practice for the calculation of such a post would have been to take the total area of the concrete and the scantlings of the post would have been reduced to 14″ × 14″. Under these conditions the concrete would have been capable of carrying a load of 196 × 600 = 117,600 lbs. The steel would then have had to support—

$$127{,}318 - 117{,}600 = 9{,}718 \text{ lbs.},$$

namely, a section of steel equal to—

$$\frac{9718}{9000} = 1{\cdot}20 \text{ sq. in.},$$

namely—

$$4 \text{ bars } \tfrac{5}{8}'' = 1{\cdot}22 \text{ sq. in.}$$

As, on the other hand, it is usual to provide that the section of steel shall be 0·8 per cent. of the section of the concrete, I have had to provide—

$$0{\cdot}8 \times 196 = 1{\cdot}57 \text{ sq. in.}$$

namely—

$$4 \text{ bars } \tfrac{3}{4}'' = 1{\cdot}76 \text{ sq. in.}$$

It is the latter method of calculation which practically all specialist designers in reinforced concrete apply to posts or pillars when they do not take into account the supplementary resistance due to the lateral binding, and, in my opinion, the restriction concerning the effective area between the bars only being utilised, should apply to those who take into account the resistance of transverse reinforcement.

Most of the designers, and I myself when calculating a post in reinforced concrete, take into account the reduction on the working stress of 600 lbs. for the concrete and consequently of 9,000 lbs. for the steel by the application of Rankine's formula. This reduction, as you know, is in function of the ratio between the height of the pillar and its width or diameter.

In conclusion, I wish to draw your attention to the following results which have been obtained from the calculation of a floor in reinforced concrete, namely, that if we are obliged to

calculate a beam fixed at both extremities with a bending moment of $-\frac{WL}{12}$ at the supports and $\frac{WL}{12}$ in the middle, we shall have to provide a very expensive construction, or we may even be faced with the practical impossibility of carrying out the work.

I am aware of the fact that it would be possible to obviate the difficulties which I have mentioned, by providing for the beams supported by pillars in reinforced concrete, gussets or brackets forming cantilevers, calculated as such, which would support at their extremities the beam itself.

It remains to be seen, of course, if this manner of dealing with the question would be allowed by the Official Rules which are now in preparation, and I fear that even if a specialist applies this method, the official controller will oblige him to provide at the points of support of the beam at the extremity of the bracket or cantilever, a bending moment of $-\frac{WL}{12}$, which would have the effect of bringing us back again to the case which I have already dealt with, with the exception that the span of the beam would be reduced to the portion measured between the extremities of the brackets supporting the beam.

I would simply draw your attention to the fact that in this case the cantilever itself could no longer be considered as a cantilever, on account of the influence of the moment of $-\frac{WL}{12}$ at its point of junction with the beam.

Concerning the posts, the numerical example which I have given shows that the formula which might be imposed is really exaggerated, when the design does not take into account the lateral resistance of the binding.

Finally, I am of opinion that Regulations framed for the purpose of becoming official and legal should not impose formulæ, but only principles enabling formulæ to be established, or, in any case, if formulæ are given, I am of opinion that these should be given as examples of what will be required, but that these particular formulæ alone should not actually be imposed.

For instance, in the discussion which I have put before you at the beginning of my lecture concerning formulæ which might possibly be adopted officially, I have mentioned formulæ for the determination of the position of the neutral axis in a slab and in a beam. Now these formulæ, which are applicable in most cases, cannot be applied in certain

special cases, as I have had the opportunity of showing you.

It appears obvious to me that an engineer or architect who may be called upon to apply Regulations concerning reinforced concrete should have a sufficient knowledge of the laws of mechanics to be able to deal with the various problems which he may have to study, and to oblige him to follow certain formulæ, would practically imply that he is incapable of exercising proper control of any scheme or problem in reinforced concrete which he may have to consider.

DISCUSSION

PROFESSOR HENRY ADAMS, M.Inst.C.E., M.C.I.:—I think the subject of this paper is most opportune. With the Official Regulations looming in the near future, we could not possibly have had a subject more important to discuss than the details of these Regulations, particularly the details which have been put before us. There are many statements made in this paper. Of course, the majority we shall probably agree with, but some of them, I must say, I do not agree with; others I do not follow, and therefore cannot say whether I agree or not.

My first note occurs on page 184. The author says, "Let us now consider the continuous beams," and, of course, it is continuous beams that are the gist of the whole paper. He says, "In this case the moments at the supports are generally greater than $\frac{WL}{12}$." There is only one case, to my knowledge, where that occurs naturally, and that is in the end span of a beam.

Then with regard to continuity between two consecutive spans. The author admits that in structural steelwork it is possible to obtain perfect continuity, that is, by the construction of the girders; but I think that it is equally possible to obtain continuity between girders of contiguous spans in reinforced concrete. It is a question in the one case of the shear strength of the rivets and in the other case of the adhesion of the metal to the concrete, and, with proper designing, I see no reason for putting the one class of work in a different category from the other.

At the bottom of the page he says, "It is obvious that the construction in this case becomes endangered, and the danger is all the greater because if one of the beams gives way the others will give way in turn." That is comparing it with a railway viaduct where, if one arch fails, the whole series of arches must of necessity fail up to the stop abutment, and that is why a stop abutment is put in. But in the case of continuous beams the severance of the continuity at one point does not necessarily affect the safety of the others ; it only makes the adjacent beams equivalent to the end beam of a series.

Immediately following the author says, "It is for this reason that in steel construction when there are several continuous spans. . . ." I think he will find that it is more a question of providing for expansion and contraction due to changes of temperature rather than to any purely mechanical consideration of continuity.

Then, in more than one place the author says, if this principle is admitted in the Official Regulations the section of steel required will have to be calculated by applying a stress in the steel equal to fifteen times the stress in the concrete. I do not find it anywhere in the Regulations ; I may have overlooked it or may have misread it, but I do not find it there.

In the four different methods to be compared in finding the width of flange of a T-beam, the third one which the author objects to is, I believe, likely to be removed from the Regulations. It is one that does not compare readily with the other three, as you will find in the example given. I think calculation gives about 60 in. for three of them and 36 in. for the one that is objected to, so that, with the author, I hope that one will be deleted in the final Regulations.

Then with regard to the beams, taking into account part of the floor slab, my view is that in the majority of cases the main reinforcement is in one direction only in the slab, and in that direction one must not take it into account as the flange of a T-beam. When there are main beams, cross beams, and the floor slab, the main reinforcement of the floor slab would come in the direction of the main beams—that is, from one cross beam to the other ; and in that case the

main beams should be taken as rectangular beams, only the cross beams being taken as T-beams. It is not quite clear whether that is what the author means here. He says, "If we consider the principal beams, we find that to the compression produced by the latter we must add the compression due to the secondary beam." I do not find any case in practice where I have to add the compression of the two different things, but, as I said, I may have misunderstood what the author refers to.

Again, on page 189 he refers to 15 times the stress in concrete for the stress in the steel, while it is constantly happening that the design is such that this ratio cannot be maintained. Mentioning pillars, the author says that the transverse reinforcement has been introduced for purely constructional reasons, only for binding together the principal bars during the concreting operation. I thought one of the chief reasons for the transverse reinforcement was to prevent the bars from bulging under the vertical load.

On page 193, the Official Regulations, it is stated, do not provide any formulæ for the compression over the supports where the reverse bending moment takes place. That point has been referred to in the negotiations, and possibly some mention may be made of it—that is, if the formulæ remain in, but if the formulæ come out we shall be able to take that with the ordinary modes of calculation.

With regard to pillars, the 0·8 per cent. of the section of concrete for the steel is a good proportion, but it is not always possible to keep to it. There are other considerations that affect the diameter of the pillar. When you want to keep it very small you may have to put more than that percentage of steel, and if you wish to keep it the same width as the main beam, then it may be that less than that percentage of steel is required.

The author refers to Rankine's formula, but the statement that the height of the pillar and its width or diameter is taken into account does not refer to Rankine's formula; that refers to Gordon's formula, and Rankine's formula is Gordon's formula with this modification, that instead of the least width or diameter being taken into account, the radius of gyration is

taken in. These are the chief points. There are many others which perhaps might be discussed. I have not gone through the formulæ in detail, as on the face they appear to be correctly stated. I would only say in conclusion that, in my opinion, all the stresses in reinforced concrete should be calculated by the ordinary laws of mechanics, and that if proper provision is made in the design it is not necessary to make any surplus allowance for reverse bending moments. (Applause.)

Mr. R. W. Vawdrey, B.A., Assoc.M.Inst.C.E., M.C.I. :—I think everybody who is at all interested in the subject of reinforced concrete ought to heartily congratulate Mons. Béhar on his choice of a paper. As was said by Professor Adams, nothing could possibly have been of more interest at the present moment than the subject which he raises, but when I come to deal with the different points in his paper I am afraid I cannot altogether agree with a good many of them.

First of all I will mention a point in which I do heartily agree with him—that is, that any such set of rules as those proposed should, in my opinion, be looked upon as a means of dealing quickly and conveniently with difficulties that may arise. A set of rules such as that proposed by the London County Council should be used for checking for safety any design which is put before an authority, but if in any particular case a competent designer wishes not to evade the rules, but to go more accurately into details, taking into account circumstances which perhaps are not covered by the rules, it does appear to me essential, if we do not wish to prevent new and progressive design, to allow a designer to substantiate any position which he wishes to take up regarding design in this material. This is in a very fluid condition—I mean that the methods of design are continually changing; they have changed very considerably in the last two or three years—and if no allowance is made for further progression the conditions which obtain at this moment are likely to be stereotyped, which, I think, would be a very disastrous business for us all. If, therefore, under any particular conditions a competent designer is able to show that what he is doing is rational, and that he is not apparently trenching unduly on the

margin of safety, he certainly ought, in my opinion, to be able to be legally in a position to put his case before the authorities, and if he substantiates his case to be allowed to proceed. If these formulæ are to be adhered to accurately in all cases, it appears to me, as I said before, that the whole business is stereotyped in its condition at this moment. That, I think, is Mons. Béhar's view, and I agree with what he says.

But with regard to some of the details, it appears to me that his paper, a good part of it at any rate, might be summed up into an argument against the use of continuity. Well, I certainly am under the impression that one of the chief advantages of reinforced concrete is the ease with which continuity can be obtained. The author admits that steelwork can be made fully continuous. As, I think, Professor Adams remarked, I utterly fail to see where the greater difficulty in making reinforced concrete continuous occurs. The author appears to treat the bending moment over a support as one which can only be resisted with difficulty. I do not see the slightest difference myself between the resistance of a bending moment over a support and that in the middle of a beam. It appears to me just as reasonable to suggest that it is impossible to resist a bending moment which exists in the middle of a beam as it is to say that there is any difficulty or danger in resisting a bending moment over a column. If he suggests that the bending moment over a column might be insufficiently guarded against, and that therefore more stress would be thrown on the centre of the beam, of course that is so ; but it is no more likely that the bending moment will be insufficiently resisted over a support than it is that the bending moment will be insufficiently resisted in the middle of the beam, and it appears to me therefore that it would be just as reasonable to design a floor in which the whole of the bending moment were collected at the point of support, and therefore taken away from the centre of the beam, as to design a building in which the whole of the bending moment were thrown on to the centre of the beam and little or no precaution for resisting the bending moment at the support was taken. That is to say, you could design two extreme cases, one being

the case of beams in which they are all separate, the whole of the bending moments being taken in the centre of each beam ; the other extreme being that in which the floor is formed by a series of cantilevers projecting from the supports, and merely meeting with a little or no connection at the centre of the span. One method would be as reasonable as the other, and I quite fail to see why one should not vary the portion of bending moment at the end of the supports or the middle with a considerable degree of latitude. The possibility of doing this is not in any way affected by the stock argument that the external moments are necessarily fixed by the external conditions of loading. That is true only when the moment of inertia of the beam is fixed at all points. If, as is the case with reinforced concrete, we can vary the moment of inertia of the beam at any point, we automatically change the moment which has to be resisted by the beam at any point.

The author does not appear to lay sufficient stress, as far as I can see, on resisting the greatest moment which must occur at any point. If the floor is designed as he suggests, with, say, a bending moment of $\frac{WL}{40}$ at the support and the greatest moment, whatever it is, in the middle of the span, if that floor is loaded throughout, however great the bending moment which has been allowed for in the centre of the span may be, the $\frac{WL}{40}$ at the support will not be sufficient to resist the bending moment which actually occurs at that point, and therefore cracks will take place at the support, and the whole load, as the author says, will be thrown on the middle of the span. In that case it will be necessary to take the bending moment at the middle of the span as $\frac{WL}{8}$, and similarly in every case it appears to me that the full bending moment which will occur at any point must be taken at that point.

Of course, the more the bending moment gets thrown into the middle of the beam, the better it is for one reason, namely, that the beam can be treated as a T-beam in the middle of a span, whereas it can-

not be treated as a T-beam over a support, and therefore, as pointed out, other provision must be made. But I do not at all see any objection to making that other provision for the bending moment at the support by means of brackets or haunches, or whatever you call them. That can usually be done quite conveniently, and I do not think there is any need to fear such an extreme compression in steel as the author evidently does fear. What is the objection to putting in a haunch or a bracket and not treating it as a cantilever, but merely treating it as deepening of the beam, which, I believe, is quite permissible under the rules?

There is one point made by Professor Adams I should like to refer to, and that is, that the main beam, which, as a rule, is running parallel to the main slab reinforcement, should not be taken as a T-beam. That, I think, would mean a very serious loss to the science of reinforced concrete as a whole, if it were upheld. Of course, the idea is, that as there is not very much reinforcement as a rule running at right angles to the main beam, the slab is not very well tied to it, and I take that to be Professor Adams's reason for objecting to the use of a slab as the compressed portion of a main beam.

Professor Adams:—I may say that is not the reason; the reason was that you have already allowed for the compression in the slab in the direction of the main beam.

Mr. Vawdrey:—I see; I misunderstood that point. Yes, I follow Professor Adams's point. At the same time, it is at the centre of the slab span only that compression approaches anything like its limit, and throughout the major portion, at any rate, of the main beam, the slab compression near the main beam is very slight. It is not until one gets to some little distance from the beam that the slab has to support itself entirely by means of its own tension and compression. The portion next the beam is supported by shear.

I would suggest that the Rules of the London County Council are very fair for use, as more or less general rules of design, and that any difficulty such as those raised by the author in his paper would be fully

met if a clause were inserted in the Regulations that any designer who wishes to go beyond the Rules in any particular must satisfy the authorities that he has good reason for acting as he proposes to do. (Hear, hear.)

If some such clause as that were added, I must say that, with a few exceptions, I see very little objection to the London County Council Rules. One objection in which I agree with the author of the paper is the fact that it does seem to me that the advantages of the particular form of spiral binding in columns are unduly magnified. Certain advantages of that particular form may sometimes, though they do not always, exist, but in any case they are unduly magnified by the London County Council Rules. And I also entirely agree with the author that where no advantage is taken of the binding by increasing the stress on the concrete of a column, one ought certainly to be allowed to include the whole area of the column as the compression section. (Applause.)

Mr. EWART S. ANDREWS, B.Sc.(Eng.), M.C.I.:—Mr. Chairman, there are not many points that I feel I should like to discuss this evening, although the paper touches on so many important points that one feels it difficult not to want to deal with a good many of them. I must say I hope the author will not be aggrieved if I do say that I feel rather disappointed with the paper in one way, because from the title I was led to expect a solution of the question as to what *is* the true bending moment of a beam in various degrees of fixity, and on reading the paper it seems to me that the principal difficulty that the author has is in satisfactorily getting in the amount of steel which his calculations show him to be necessary if he assumes what is commonly taken to be the bending moment at the fixed support, namely, the $\frac{WL}{12}$.

This subject of fixed beams and continuous beams is one at which I think I might study for very many years and never come very much farther out of the wood. It is a subject which is fraught with difficulty. In the first place, I would like to point out that the argument and theory upon which this

$\frac{WL}{12}$ is obtained, is based upon the assumption that the beam has a constant moment of inertia, and that assumption, of course, does not hold in the case of a beam in which you have the reinforcement at the bottom and then bent up and used over the support. That, in the actual case, more nearly approximates to the case of a fixed beam of uniform strength. In that case you would have the point of contra-flexure of the beam at one-fourth of the span, instead of at ·211 of the span, is it not, of the ordinary assumption? And that has the effect of increasing the bending moment at the end and bringing it up to as much as $\frac{3\,WL}{32}$; it will have the effect of increasing the bending moment at the end, because it increases the effective length of the part which is called the cantilever part.

In the consideration of any formulæ of this kind, it seems to me that we want to try and get some more evidence upon the subject of what exactly are the bending moments at the fixed end of the fixed beam, because, if we are going to attempt to make our calculations to allow for a fixed end and to avoid the development of the cracks which must occur, if no reinforcement is made, then if we calculate satisfactorily, say, for the $\frac{WL}{12}$, if that *is* the bending moment, there is no reason to worry, it seems to me, about the $\frac{WL}{8}$ which would occur if we had cracks, because there is no reason to suppose that the cracks will ever develop. I do not know whether the meeting is following me; it is rather a troublesome subject to discuss without diagrams.

It seems to me rather that the author has started off on the subject of fixed beams and discovered difficulties and almost grievances in the Official Regulations relating thereto, and has not been able to keep out of other difficulties and grievances which are not really relevant to the subject. For instance, the pillars. The treatment on page 193 of the paper is one which is of very great importance in this matter, because if you are unable to make any slab allowance at the end, if the slab is, as it were, at the wrong end to be of

any use to you in the resisting of the compression, then you really have a beam in which you must have double reinforcement, and, as the author says, on the ordinary assumption where you allow for the concrete in compression, you have to have very much more steel in the compression side than in the tension side.

I have worked at this problem several times. It seems to me to be only reasonable that in such circumstances we ought to be able to throw over the compressive resistance of the concrete altogether and merely consider our beam as made up of two steel sections which are held at a suitable distance apart in much the same way as Fig. 2 in the paper; A_t and A_c will be just two steel bars which might form, as it were, the flanges of a plate girder or a Warren girder, the concrete acting as the web or as the diagonal. For that to be possible, of course, it is necessary to get cross-binding of the reinforcement to prevent the buckling effect on the compression side, but I think that that could easily be allowed for and still economy would be effected.

I might just make one remark in regard to Professor Adams's speech. I did not quite follow the reason for the main beams being calculated as rectangular only, and for no slab to be allowed as part of their flange. It seems to me that even if we calculated for the compression in the slab, as it were, by itself, to take its own little piece of the load, when we come to calculate the stress on the main beams we do not restrict ourselves to the remaining part of the load; at least, I do not think that is the intention; we do not restrict ourselves just merely to the part of the beam which we consider as part of the slab, but we take the whole load as being carried by these principal beams so that the fact that we have already allowed a certain compression in the slab to take its part of the stress is no reason why we should not allow part of the slab as part of the T-beam in taking out the main stress for the principal beam.

Mr. MORGAN E. YEATMAN, M.A., M.Inst.C.E., M.Am.Soc.C.E., M.C.I.:—I would say, first of all, that I heartily agree with the author's general conclusion as to not being bound by formulæ without

any discretion, and if it is likely that formulæ will be officially adopted it is a very good thing that we should have a discussion on them and see what is likely to be put before us.

As regards the columns, I entirely agree with Mons. Béhar, and I think general practice is unanimous on that, that where only a moderate compression, not exceeding 600 lbs., or perhaps some lighter load, as 500 lbs., is allowed on the concrete, the whole section of the concrete is taken into consideration. When, on the other hand, a higher compression is allowed in consideration of the increased strength due to hooping, only the section inside the hooping can be considered; for it is obviously the case that where such columns are tested to destruction the outer concrete scales right off by the time the inner concrete gets up to its maximum load.

In the beams we face a more difficult question. I had occasion, at a recent discussion at the Institution of Civil Engineers, to protest against making too great an allowance for continuity. The continuity is there undoubtedly, but you must remember that the loads are not always on all the spans at the same time. It is rather a difficult matter, or a long matter at any rate, to calculate it for a large number of spans, but I have worked out for three spans the abutment loads and the maximum moments under different conditions. Now, in the middle span the maximum is $\frac{3}{40}$ WL, supposing it to be of uniform section all through, as it is taken in most calculations, though this is not altogether the case in fact.

Mr. E. FIANDER ETCHELLS :—Uniformly loaded?

Mr. YEATMAN :—Uniformly loaded. The maximum moment on the centre span is $\frac{3}{40}$ WL—that is, at the centre of the centre one when it is loaded and the other two are unloaded.

Mr. ETCHELLS :—That is, the live-load moment only, exclusive of the moment of the dead-weight of the beams themselves?

Mr. YEATMAN :—That is right; that is for the

live-load only. Now, the maximum moment on the end span is $\frac{81}{800}$ WL ; it is a little greater than one-tenth, and that is obtained when the two end spans are loaded and the middle span is unloaded. The maximum moment over a support is $\frac{7}{60}$ WL, which is obtained when one end span and the central span are loaded and the other end span is unloaded. When all the spans are loaded, which, of course, is the case for that part of the load which is dead-load, the moments over the supports are $\frac{WL}{10}$. In the middle of the middle span it is $\frac{WL}{40}$, and at the maximum point on the end span it is $\frac{2\,WL}{25}$. With the central span only loaded the maximum moment at the centre is $\frac{3}{40}$ WL. Now, that shows that except in the middle span you are liable to have moments both at the centre of the span and over supports slightly exceeding $\frac{WL}{10}$; but, of course, as Mr. Etchells was suggesting to me, in all practical cases there is a uniform dead-load, as well as the variable load which may or may not come on the span. On the ratio between those two will depend what the actual maximum is in any case. In Turneaure and Maurer's book on Reinforced Concrete that question is discussed, and they gave the maximum for two and for three spans, with, I think, the ratio of 2 live to 1 dead ; and, that being a usual proportion, they show that it is not, in general, safe to reckon on any less moment than $\frac{WL}{10}$, and I believe the universal practice, both in France and the United States at any rate, is to calculate continuous beams in actual construction for $\frac{WL}{10}$.

AN HON. MEMBER :—At the supports?

MR. YEATMAN :—Well, I am considering the beams as of practically uniform section. In rectangular beams there is no difficulty about that, because

if you put in reinforcements symmetrically naturally you will get the same strength at the supports and in the middle. When it comes to T-beams, we are certainly landed in a difficulty by the fact that over the supports we have no T to take the compression, and we can hardly provide one in concrete. I think the alternative of deepening the beam at the support by a bracket is a very good one. Certainly any method which leads to the putting in of three times the quantity of steel in compression at the support that you have in tension at the middle of the span is an irrational one, for to use heavy steel reinforcement in compression at about 6,000 tons per square inch is not an economical way of treating the material. If that had to be done, it certainly would be more economical to sever your continuity and provide an ordinary beam with $\frac{WL}{8}$ at the centre.

But I think every practical constructor will agree that, having done that, you would not have increased your strength by severing the continuity. It would be better to leave the continuity for what it is worth, and in practice I do not think you will go far out if you provide for $\frac{WL}{10}$ at the centre and carry about the same amount of metal over the supports; say, let half your bottom rods run through over the supports, half of them turn up and be carried through at the top over your supports, and if you have any compression rods or top rods in the centre, carry those through over the supports. I think with that form of reinforcement, and calculating at the centre for $\frac{WL}{10}$, you will get a very practical and efficient construction.

I must say I entirely agree with Professor Adams as to the danger of calculating the slabs as tables to the main beams—that is, in the kind of construction where the secondary beams or joists are much closer together, centre to centre, than the main beams or girders. In that case the floor slabs span from joist to joist, the tension in that direction is taken by rods and the upper part of the floor is in compression, to whatever amount of compression is allowed, parallel

to the main beams and at right angles to the joists. Well, if you make the main beam a Tee you put a compressive strain on that slab, which must necessarily be added to the compressive strain which is on the top part of it already. In the bottom part of the slab there is a compression put on by the use of the Tee which negatives the tension that there would be in the bottom part of the slab, and at the top over the abutments it is in the opposite direction; but at the centre of each small span necessarily the maximum compressive strain, both from action as a Tee beam and from action as a slab, is at the top extreme fibres. We find in point of fact that those two compressions will be added together; therefore, if you are to count it as both you must allow for the maximum strain to be safe under the two compressions. It is the same thing as frequently happens in steelwork in calculating, say, the top member of a roof stress; it is in compression as a member of the truss, and it is in tension at the bottom and in compression at the top as a beam between two points of intersection, and you must calculate the extreme amount of strain as the sum of the compressive strain from the bending and the compressive strain upon the member as a whole. So in our case it certainly is wise to be careful how you allow for the Tee in the main beams. Of course, in a square panelled floor, with the reinforcement in both directions, the same will apply to secondary as well as to main beams, but in the floor with the joists near together there is no danger in using the floor as a Tee to the joists, because the compression in one direction from the local bending does not impair its strength to withstand compression at right angles to it from the Tee action.

But the whole thing points to the conclusion that the author has arrived at, that it is both difficult and dangerous to lay these things down by hard-and-fast formulæ. These things must be designed by people who understand them—at least, they ought to be. (Applause and laughter.)

MR. ETCHELLS:—It is a big "ought."

THE SECRETARY (MR. H. KEMPTON DYSON) read the following contribution from MR. D. WEBSTER ROBERTSON, M.C.I.:—

Unable to attend Mr. Béhar's lecture, I am thankful to have been privileged to peruse his paper, which deals in detail with the theoretical work in reinforced concrete design.

It is depressing to open book after book and find that the authors go accurately into the straightforward part of the business, developing formulæ, etc., then dispose of vital points, such as the amount of fixity in a beam, with the remark that "this must be left to the judgment of the designer."

Mr. Béhar has made a successful attempt to treat the matter rationally.

I wish, however, to put the following questions, not with any fault-finding motive, but they are the sort of questions that might arise between a specialist contractor and the authority by whom his drawings have to be approved :—

(1) In the examples worked out by Mr. Béhar $\frac{WL}{12}$ has been employed for all the slabs. Does he claim that the outermost beams "a" are sufficiently rigid to give the outer slabs "fixed ends"? Should these slabs not be treated as "one and fixed" with $\frac{WL}{8}$ on the other bearing?

(2) The compression ends of the slabs are stressed to 600 lbs. per square inch in the first instance, and then in conjunction with the principal beams they receive an additional stress of 600 lbs. Is this permissible?

(3) The principal beams are treated as having "fixed ends." The fixing, therefore, must be provided by the columns, and must produce a considerable bending moment, for which no provision has been made in the design of the columns. The beam, in addition to imposing a direct load of 127,318 lbs., subjects the column to equal and opposite thrusts, at a distance of about 2 ft. apart, of, roughly, 170,000 lbs.

Mr. HERBERT E. STEINBERG, Assoc.M.Inst.C.E., M.C.I. :—I should like to add my word of thanks to the author for the trouble he has taken in preparing the paper, but I should like also to dissociate myself almost entirely from the statements contained therein.

It seems to me, first of all, desirable to clear up the difference between a beam with fixed ends and a continuous beam. The author rather falls into the error of treating both as though they were one and the same thing. The question of continuous beams is one that can be solved with almost the same accuracy as the ordinary single span beam with free supports, having a bending moment of $\frac{WL}{8}$. The only point on which there can be any doubt is as to whether it is permissible to assume the beam as having a constant moment of inertia. There are, however, experiments, chiefly German experiments, which go to prove that that is quite a reasonable working hypothesis, and, therefore, once a constant moment of inertia is adopted you can calculate, as one of the speakers has already calculated, the bending moment for a continuous beam of any number of spans under any condition of loading.

The Regulations proposed by the London County Council lay down fairly clearly what you are to do with beams when loading is evenly distributed, but there is also the difficulty of a continuous beam in which the loads are applied at points of the beam and are not distributed uniformly throughout the length. The various spans of the beam may also be unequal. Occasionally one comes across a building where the columns stop at the first floor beam, which thus has to carry point loads from two columns. It is still a continuous beam, but it would be ridiculous to apply bending moments of $\frac{WL}{12}$ or WL over any factor done by guess-work. The only thing to do is to calculate it properly by the established theories for the treatment of continuous beams.

With regard to beams with fixed ends, the amount of fixity usually depends not upon the beams, but upon the part of the structure which takes the end of the beam. For instance, if there is a sufficient height of brickwork above the built-in end of the beam, a negative bending moment, or a counter-clockwise bending moment, sufficient to neutralise the clockwise bending moment in the beam, may be developed, and therefore it may realise a truly fixed end, in which case the bending moment at the middle of the span

will then be relieved until it becomes $\frac{WL}{24}$. Even in this case it would not be prudent to adopt $\frac{WL}{24}$, and, therefore, if you really want to make the best job of it, and that is by taking the most pessimistic view, you would calculate the bending moment at the ends of the beam as though they were perfectly fixed, and you would calculate the bending moment in the middle of the beam as though the ends were imperfectly fixed. If you are in competition and you have to keep down the weight of steel, of course you do not do this. (Laughter.) In any case, however, the greatest thing is to realise what you are doing and why you are doing it; these figures, $\frac{WL}{12}$, $\frac{WL}{40}$, $\frac{WL}{10}$, have no particular significance, and it would be just as reasonable to take $\frac{WL}{9}$ or $\frac{WL}{25}$ or $\frac{WL}{37}$ or anything you like. If you must guess them, guess them anyhow, but do not pretend there is any theoretical justification for so doing.

The London County Council propose to lay down a bending moment of $\frac{WL}{12}$, and as a general rule is a very reasonable proposal. It is not nearly so severe as the German Regulations, where, I believe, if you cannot calculate the bending moment accurately, you are forced to take $\frac{WL}{8}$ over the support, and $\frac{WL}{10}$ in the span. The London County Council bending moments allow more latitude than that.

There is another fundamental fallacy into which, to me at any rate, it appears the author has fallen, and one or two speakers have also seemed to imply the same error, viz., that by taking a bending moment of a certain amount at one point in a beam you thereby reduce the bending moment at another point in the beam. You can do nothing of the sort.

The bending moment is not a thing over which you have any control at all; it depends on the loading of the beam and the span of the beam. What you have to do is to try and estimate it by calculation as

accurately as possible. Because you may have determined, in your superior wisdom, that bending moments in the span shall be $\frac{WL}{12}$, and over the support $\frac{WL}{40}$ the actual bending moment over the support will not change, nor will the true bending moment in the span alter. If you put in sufficient steel for $\frac{WL}{40}$, then as the bending moment you have taken is not enough, the steel will be overstressed and the concrete will crack, and your bending moment at the middle of the span will become greater than you assumed. But that is not designing; that is simply silliness. (Laughter.)

After all, people who are supposed to be specialists —I am speaking as specialist—in a few years' time will have to justify their existence by being more expert at their work than, say, an amateur designer taking up reinforced concrete as a sort of hobby.

Then with respect to the author's arguments and calculations with regard to the factor of safety in a building, it does not appear to me to need any laborious proof that it is more safe to take $\frac{WL}{12}$ than $\frac{WL}{40}$; $\frac{WL}{8}$, $\frac{WL}{6}$ would be still more safe.

Then, again, with regard to continuity, I quite agree with one speaker—I really forget who it was— that there is no earthly reason why the bending moment over the supports should not be just as reliable as the bending moment in the centre of the span, or why only the bending moment over the supports should be subject to all the ills of bad workmanship and unsuitable materials, and not the bending moment at centre of the span also.

One speaker gave the maximum bending moments for various conditions of loading on a girder of three spans with the ends free, and he said the bending moment for the dead-load which cannot change from span to span has a maximum of $\frac{WL}{12 \cdot 5}$ in the end span, $\frac{WL}{10}$ over the first support, and $\frac{WL}{40}$ in the centre span.

Now the superload may exist on all the spans, on the centre span only, the end span only, or it may exist on the two end spans ; these four cases must therefore be calculated, and the worst possible bending moment taken from each case. When these have been added to the bending moments of the dead-load the work will have been done as accurately as possible, and then if the area of concrete and the reinforcement is calculated according to those bending moments the best possible job has been made of the work.

Now the author says, if you adopt anything like the above procedure, you are led into great difficulties with your bending moment over support, owing to the small area of concrete in compression, but I do not think you are. He suggests that to adopt Monsieur Considère's method of putting spirals in the underside of the beam is satisfactory, but as the spiral reinforcement is still controlled by a patent in this country it cannot be universally adopted. But how is it that in Germany, where, as I say, the bending moment over the support is to be taken as $\frac{WL}{8}$, and Considère's spiral patent also holds, an enormous amount of reinforced concrete is done annually to the stringent Official Regulations? If it were almost impossible to design with $\frac{WL}{12}$ over the support, as the author suggests, it would be perfectly prohibitive with such a regulation as $\frac{WL}{8}$.

The examples that the author gives are not chosen in a very practical way. He could easily have made his beams wider, he could easily have put gussets on to them, or done two or three things, and he would have got over his difficulties. Of course, I suppose he chose an example in order to make the difficulty obvious.

With regard to the method of putting in spirals in the lower side of beams near the points of support, that the author apparently considers to be a good and satisfactory method, and, as an admirer of Mons. Considère, the inventor and patentee of the spiral, I fully agree with him, but it is not essential to overcome the difficulty in this way. It may make the best job of

it, but there are other, if less perfect, solutions to the problem.

Then, there was a point which has been raised by various speakers with respect to the compression of the concrete in the slab. Apart from the fact that the compression in the slab due to the bending moment in the slab exists only for about one-third of the way down, there is also another fact, viz., that quite apart from how you consider it—you can consider it how you like—immediately a slab passes over the beam it is prevented from deflecting in the direction of its span, and, therefore, there is no bending moment and no compression in the slab at that point due to its own action, and this effect extends for a considerable area on either side of the beam, so that even, although on paper the arrangement of the beam may look as though the slab was doubly compressed, in practice it cannot possibly be so.

There is also a statement that the French have different Regulations for secondary beams from those which they insist on for main beams. That is on page 188. I am not at all sure that that is correct.

I have one or two points in which I agree with the author, and first with regard to columns. I think that it is quite reasonable that the cover of concrete should be recognised as contributing to the strength of the columns. Of course, if you enhance the value of what you might call the "basis stress" of the concrete by putting either a series of ties closely together, or by a spiral, you put a larger stress on your concrete core than on the plain concrete. But, nevertheless, I think that the large area outside the round or square core might be taken at, say, 600 lbs. per square inch. I see no harm in that at all. The cover inevitably contributes to the strength of the column, and there are numbers of experiments to prove that the more you reinforce the core, the higher you raise the point at which the cover begins to peel off, so that there is really no reason against assuming that the cover of the concrete outside the core does work at something or other; I think, therefore, 600 lbs. or 700 lbs., the ordinary basis stress on the concrete, might be taken as the figure.

Then, on page 202, there is a paragraph or two about

the cantilevering action of the beam. Personally, I do not agree with that way of looking at the problem at all. If you put in gussets in the beam they are still part of the beam, and although there is undoubtedly some inaccuracy in assuming a constant moment of inertia, yet it is small compared with the other assumptions one is forced to make. If, therefore, you recognise the beam as being continuous, and if you assume that it has a constant moment, and you calculate your bending moment for every possible contingency of loading as accurately as you can, I do not care whether the Regulations as laid down anticipate your particular case or not, but I do not think you would have any difficulty in getting your drawings passed by the authorities. But if, on the other hand, you desire to take bending moments much less than $\frac{WL}{12}$, without any theoretical justification, then I think very rightly the Regulations will stand in your way.

MR. E. FIANDER ETCHELLS, F.Phys.Soc., M.Math.A., A.M.I.Mech.E., M.C.I. :—I have pleasure in moving a vote of thanks to the author. The adoption of reinforced concrete work depends upon two factors—first, its cost, and, second, its safety, and we should seek a reasonable compromise between these two divergent ideals—*i.e*, we want the greatest stability with the least cost.

I have heard the doctrine that reinforced concrete is subject to the laws of a super statics of a recondite character, and that reinforced concrete construction is one of the occult sciences, whose laws transcend the laws of physics and of ordinary matter.

But now that phase is passing away, even among the specialists themselves. The specialists have tried to lift reinforced concrete out of its cradle of empiricism and put it on a more settled basis.

The British specialists have recommended that in all important cases the bending moments under all possible conditions of loading should be accurately determined, and the beams designed at each point in their length to resist the maximum bending moment which may occur at such point, but that for small ordinary floors a sufficiently accurate result would be

obtained by using a bending moment of $\frac{WL}{12}$, both over the support and in the centre of the span for continuous beams.

The Second Report of the Joint Committee of the Royal Institute of British Architects recommended that the bending moments should be calculated on ordinary statical principles, and the beams or slabs designed and reinforced to resist these moments. Where the maximum bending moments in beams or floor slabs continuous over three or more equal spans, and under uniformly distributed loads, were not determined by exact calculation the bending moments should not be taken less than $+\frac{WL}{12}$ at the centre of the span and $-\frac{WL}{12}$ at the intermediate supports.

This raised the question as to what the ordinary statical principles were. Would it be in accordance with the ordinary statical principles if, knowing that there is a bending moment of $\frac{WL}{12}$ at the support, we only provided for $\frac{WL}{40}$ or $\frac{WL}{24}$?

This report speaks of exact calculations, but the most exact calculations we have are based principally on Clapeyron's famous theorem of three moments, which was first published in *Comptes Rendus* about 1857. It is based on several assumptions, one of them being the constancy of the inertia moment. To solve the problem it is necessary to employ the double integration of a differential equation, and though you work out the numerical result to the furthest decimal, what is the good of the result if there is a basic assumption that is far from the truth?

Speaking of steelwork, where there is admittedly a greater degree of continuity, in general it may be said that the bending moments at the supports next the end are always greatest, and are there about $\frac{WL}{10}$, and near the centre supports they are nearly uniform at about $\frac{WL}{12}$.

Since the Draft Regulations were written we have from America, the land of up-to-dateness, two further Reports, or Codes, and they both fully support the Draft Regulations in respect of the bending moments. The Joint Committee representing the American Society of Civil Engineers and the principal scientific institutions over there recommend, "That for beams the bending moment at centre and at support for interior spans should be taken at $\frac{WL}{12}$, for both dead- and live-loads." Then, again, it goes on to say, "For spans of unusual length more exact calculations should be made. Special consideration is also required in the case of concentrated loads. Even if the centre of the span is designed for a greater bending moment than is called for by the previous paragraph, the negative moment at the support should not be taken at less than the values there given." Furthermore, it is stated that, "In the design of Tee beams acting as continuous beams, due consideration should be given to the compressive stresses at the support."

The New York Code which came into force this year states that "The bending moments at centre and support for beams or girders continuous over two or more supports shall be taken at $\frac{WL}{12}$." The Regulations of the Royal Prussian Ministry say that "If conditions at support produce restraint and continuity of slabs and beams, the bending moments which appear at those points must have reinforcement placed near the upper stressed surface in proportion to the bearing area.

If a continuous beam or slab cannot be computed, or, in regard to the latter, if no restraint is certain at a beam or wall, then, with equal panels and uniformly distributed load, the moment is not to be taken less than $\frac{WL}{8}$ over the supports or than $\frac{WL}{10}$ at the centre of panels."

It has been said that the Draft Regulations under discussion would prohibit the use of reinforced concrete, that it would kill the trade. In reply, I ask whether the reinforced concrete trade is dead in Germany? Is it dead throughout the United States?

With regard to the breadth of Tee beams, we are also told that the Regulations will militate against the use of reinforced concrete, but that does not seem probable when we bear in mind that the particular Regulation referred to was suggested by the Committee of Specialists themselves. They unanimously, and on their own initiative, recommended that the width of the area under compression in Tee beams should not be greater than fifteen times the thickness of the slab or flange.

The New York Code, revised this year, states that the breadth of the compression flange of the Tee beam should not exceed twelve times the thickness of the slab plus the breadth of the rib. Therefore it would appear that the regulation under discussion of fifteen times the thickness, as recommended by the specialists themselves, is apparently good practice, and also more or less accords with international practice.

Take the ratio of the breadth of the flange to the span of the beam, the Regulations of the Royal Prussian Ministry say you shall only take one-sixth of the span as the breadth of the flange. The New York Revised Code gives the same figure. The American Joint Committee are a little more lenient ; they say you may take one-fourth of the span.

The London County Council Regulations allow twice the width of the Prussian, twice the width of the New York, and permit a breadth of one-third of the span. The complaints seem to arise irrespective of the weight of evidence.

With regard to formulæ generally, it appears to me that formulæ represent the engineer's shorthand, and are a symbolic method of representing the truth, and so long as we do not mistake the symbol for the truth itself all will be well.

Formulæ, after all, are merely epigrammatic methods of stating the laws of science.

It has been well said that "in physics the memory disburdens itself of its cumbrous catalogue of particulars and carries centuries of observation in a single formula."

The Regulations are given in words or in formulæ, whichever are the most convenient.

Equations are vitally necessary, and they are neces-

sary to ensure that the stresses are within the limits set by the Regulations. Every one has known that many times people have made the assertion that the stresses were under 600 lbs. per square inch, after having made their own assumption about the bending moment. You know you have only to make the denominator in the bending moment equation what you like and you will get your stresses low enough to comply with any Regulations. (Applause and laughter.)

Mr. Béhar stated that he was of opinion that regulations framed for the purpose of becoming official and legal should not impose formulæ, but only principles enabling formulæ to be established ; or, in any case, if formulæ was given, he was of opinion that these should be given as examples of what would be required, but that these particular formulæ alone should not actually be imposed.

I suggest that if principles only were given very few architects, surveyors, magistrates, or builders would be able to truly affirm whether the statical requirements of the regulations had been complied with. If merely principles were laid down we would require to be Rankines, Clapeyrons, and Eulers as well to convert the basic principles into a form that would be suited for the practical work of design.

Basic principles might please the professors of engineering, but would they help the busy builder who had to put up buildings in a hurry?

Mr. Béhar stated that he was of opinion that an engineer or architect who may be called upon to apply regulations concerning reinforced concrete should have a sufficient knowledge of the laws of mechanics to be able to deal with the various problems which he may have to study, and to oblige him to follow certain formulæ would practically imply that he was incapable of exercising proper control of any scheme or problem in reinforced concrete which he may have to consider.

I hold that such a conclusion is unjustified. The architects and engineers were consulted before any Regulations were sent forward to the allowing authority. Then, since the architects and engineers were consulted before the Regulations were made, such consultation effectively admits their competency not

only to carry out the works, but to criticise the draft and to participate in the work of law-making.

I maintain also that it would be easier to see whether a particular design complied with certain stresses than it would be for the building authority, or any officers of the building authority, to discriminate as to who were competent and who were not. That would be a very arduous task and a very difficult task, and one open to very grave abuses ; and it is much easier to judge a plan than to judge a man.

MR. BÉHAR then made some remarks in reply to the discussion, but as time did not permit of a full reply he has sent the following contribution in writing :—

Professor Adams has stated that the moment at the point of support in the case of continuous beams is not always greater than $-\frac{WL}{12}$. This assertion is correct, but what I have endeavoured to point out to you in my lecture is, that in reinforced concrete, by reason of the assumptions which we have to make, to apply the formulæ of continuity we have to apply at all the points of support the greatest bending moment which we have found for one of the supports, and this moment is always greater than $-\frac{WL}{12}$.

In order to throw more light on this subject let us consider a reinforced concrete floor, in which we have to study a series of twelve continuous beams. Professor Adams, I suppose, will agree that it would not be wise to apply the continuity to the twelve spans, and I take it that he will require the latter to be divided into a certain number of sections—for instance, three sections of four spans each, the continuity being applied only to each of these particular sections. We have, therefore, a section of four beams resting on five points of support.

In order that we may be able to apply the theorem of Chapeyron we must assume that the moments at points of support 1 and 5 are equal to 0, and if we are dealing with equal spans and equal distributed loads we shall have, for the other supports, moments equal to—

$$B_2 = B_4 = -\frac{3}{28} WL > -\frac{WL}{12}.$$

$$B_3 = -\frac{2}{28} WL < -\frac{WL}{12}.$$

On thirteen points of support we have, by assumption, the following :—

Supports 1, 5, 9 ... ... Moments $= 0$.

Supports 2, 4, 6, 8, 10, 12 Moments of $-\frac{3}{28}$ WL.

Supports 3, 7, 11 ... ... Moments of $-\frac{2}{28}$ WL.

Owing to the peculiar nature of reinforced concrete constructions, in which the supports of the beams are constituted by other beams or posts in the same material, it is obvious that the free supports do not exist, and I take it that Professor Adams would not consider the points of support 1, 5, and 9 without reinforcement to resist negative bending moments, the value of which, however, is in reality unknown. Moreover, we may take as the starting-point of a section of four spans any particular point of support, so that we would find ourselves obliged, by measure of precaution, to assume that the greatest moment found for one of the supports should be applied to all the supports.

If the total length of the twelve spans had been divided up into groups of three beams the greatest moments on the supports would have been $-\frac{WL}{10}$; I think, therefore, I was right in saying that in continuous beams it is necessary to provide at the points of support a moment greater than $-\frac{WL}{12}$.

Professor Adams is of opinion that in these beams the compression of the slab must not be taken into consideration, for the reasons which he has given. Mr. Vawdrey has answered upon this point. I would take the opportunity, however, of the question raised by Professor Adams to explain more clearly my method of reasoning concerning this matter (pages 187 and 188 of my paper), which has appeared rather obscure, to

some of the members of the audience, amongst others to Mr. Etchells, who is fathering the Rules which are at present under discussion.

Let us consider a slab supported by secondary beams in reinforced concrete (Fig. 1), and let us examine a square portion of this slab having 1 sq. in. in area, of which the centre is situated at the point of intersection of the two axes passing at the middle of the span of the slab and at the middle of the span of the secondary beam. The upper face of the element A under consideration will be submitted to an effort of compression F, owing to the flexion of the slab. This effort of compression will be normal to the direction of the secondary beam, and owing to the flexion of the secondary beam the element A will also be subjected to an effort of compression directed in a parallel direction to the secondary beam. Therefore the resultant force R of these two forces F and F^1 might be greater than 600 lbs. per square inch, inasmuch as the force F is already itself almost equal to 600 lbs. if we assume that the slab is free to bend on the entire span, between the secondary beams, without being influenced in any way by the flexion of a portion of this slab working with the secondary beams, which, in fact, would be exaggerated.

Let us now examine the compression of the slab when the principal beam comes into play (Fig. 2). Let us consider an element B having 1 sq. in. in area and situated on the upper face of the slab at the middle of the span of the secondary beam, which is nearest to the middle of the principal beam.

This element B receives a compression F, coming from the flexion of the secondary beam, and directed normally to the main beam. This element is not influenced in any way by the slab, because in reality the entire area *b* is deflected with the beam. From the main beam the element receives a compression F^1, acting in a parallel direction to the principal beam. The resultant R of the two forces F and F^1 will be generally less than 600 lbs. per square inch, because the forces F and F^1 will be usually much less than 600 lbs. per square inch, if the whole area 1 of the secondary beam and the whole area *b* of the main beam are taken in consideration.

FIG 1

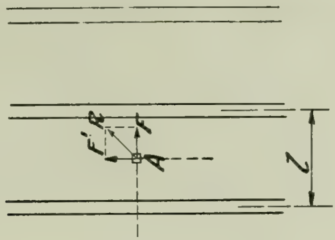
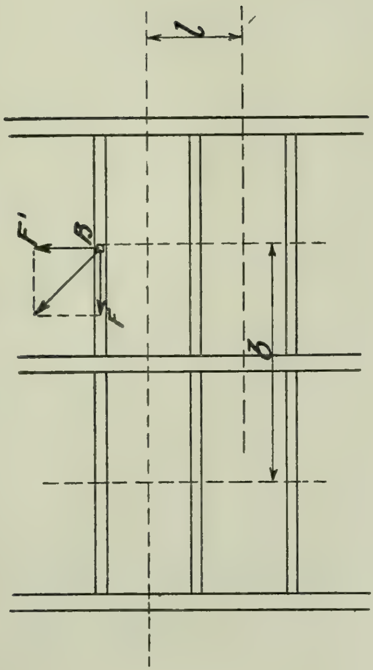


FIG 2



I conclude by what precedes that, for the principal beams, the Regulations should be less stringent in the determination of the width *b* to be taken into account in the calculations.

Mr. Vawdrey holds the same opinion as Professor Adams in saying that the formulæ of the Regulations should not be imposed, but should simply be set forth as a guide. I am entirely of their opinion on this point, as shown by the concluding remarks of my paper.

Mr. Vawdrey also states that he does not see why continuity should not be applied to reinforced concrete. I do not say that the method of continuity should not be applied. I have simply drawn your attention to the fact that in my opinion the method of continuity is farther from the reality in reinforced concrete than in steel construction, unless we assume at all the points of support the greatest bending moment found for one of these points, as I have pointed out in my answer to Professor Adams. Continuity finds a better application in bridge-work, especially when the points of support of the beams are constituted by a series of piers, the ends of the bridge being supported by masonry abutments.

We must not lose sight of the fact that the theorem of Clapeyron is based on three fundamental assumptions :—

(*a*) That the moment of inertia of any section of the beams is constant.
(*b*) That all the points of support are on the same level.
(*c*) That the points of support are simply represented by lines, or, in other words, a sharp edge at each point of support.

The first of these conditions is never ensured in reinforced concrete beams.

Concerning the third of these conditions, although this might be assumed for secondary beams resting upon principal beams, I fail to see how this could be attained when the beams are supported by pillars, the scantlings of which in certain cases reach 24 in., especially when these posts are supporting other posts above, transmitting heavy loads. In such cases we

would have a perfect fixation, and $-\frac{WL}{12}$ could be imposed with $\frac{WL}{24}$ in the middle of the beam—that is, if we wish to be in perfect accordance with the laws of mechanics. I am not of opinion, however, that this should be done, as this would lead us to have an insufficient amount of steel in the middle of the beam, which would cause the latter to be weak if by any chance the amount of fixture at the points of support had been overestimated.

Concerning the assumption (*b*), I would simply say that it may happen that in floors supported by a certain number of pillars some of the latter may sink more than others, owing to defective foundations, and if this were to happen it is possible that the span of one of the beams instead of being 1 might become 2×1, owing to the sinking of one of the intermediate supports. Unequal sinking of any pillar is, however, less likely to happen in reinforced concrete than in any other material, owing to the monolithic nature of the construction.

I will deal with Mr. Steinberg's argument against the points of support with a moment of $-\frac{WL}{40}$ at the same time as I answer Mr. Etchells on this point. Concerning the gussets in the beams, Mr. Steinberg is unwilling to assume that these should be considered as cantilevers, but simply as an increased height of the beam at the points of support. I hold the opinion, on the contrary, that if the gussets are properly reinforced we may treat these as cantilevers without endangering the construction, and this has the advantage of bringing about an economy in the construction.

In further reply to Mr. Steinberg, he states that the moments of $-\frac{WL}{40}$ and $\frac{WL}{10}$ or $-\frac{WL}{24}$ and $\frac{WL}{12}$ are only guesses—namely, that we assume one or the other at the supports or at the middle of the beam, and that the other corresponding moment is determined by calculation. These, however, are not guesses, but assumptions which are made in the same manner as those which he himself would have to make in calculating continuous beams when he assumes, in order

to apply the theorem of Clapeyron, the various hypotheses which I have mentioned in my answers above.

Mr. Steinberg says that all we have to do is to increase the width and height of a beam or secondary beam at the point of support in order to take up the compressive resistance at these points. He probably forgets that floors in reinforced concrete depend upon the requirements of architects more than upon the engineer designing the scheme. Very often the height and the width of the beams have been fixed to satisfy other conditions which have nothing to do with the calculations. What would he do in this case to resist high compressions with a stress of steel limited to 6,000 lbs., or even to 4,000 lbs. only, per square inch?

Mr. Etchells has told us in the discussion of my paper that the Rules of the London County Council specify $-\frac{WL}{12}$ at the supports, whereas the Prussian Regulations stipulate $-\frac{WL}{8}$.

I should like to know how those engineers who have to apply these Regulations overcome the difficulty of the compression of the points of support, which I have mentioned above. Mr. Etchells, however, has forgotten to tell us that these same Prussian Regulations authorise a working stress of the concrete in tension, and attribute to the latter a stress equal to two-thirds of the crushing stress of the concrete in tension, and as they assume that the resistance to crushing in tension is equal to 228 lbs. per square inch, the application of these Rules would lead us to have a width *b* of the slab working in tension, at the same time as the beams at the points of support, at an average stress of 120 lbs. to 140 lbs. per square inch. On this account the bars in tension at the points of support will represent a section of steel certainly much less than the section which we obtain by the application of the formula $-\frac{WL}{12}$ of the proposed Regulations of the London County Council.

Concerning the compression at the points of support we do not know whether the Prussian Regulations stipulate that the section of steel shall be calculated by applying to the latter fifteen times the working stress

of the concrete applied to the centre of gravity of the bars, whereas the proposed Regulations of the London County Council actually adopt this view.

To conclude my answer to Mr. Etchells's remarks, the aim of my paper has not been to try to urge that certain methods of calculating a moment for a beam in reinforced concrete should be adopted, in preference to any other method, but to show that a greater safety could be obtained by providing at the middle of a beam a bending moment higher than $\frac{WL}{12}$, or at least equal to this value, and to show if the method of calculating beams as continuous may be sometimes dangerous, it is precisely because by this method one is led to provide, in certain cases at the middle, bending moments which are smaller than $\frac{WL}{12}$, whereas at the points of support, if the designer of a scheme provides reverse bending moments less than $-\frac{WL}{12}$, the danger is not so great on account of the table *b* of the slab, which is working in tension at the same time as the beam. In fact, to a certain extent, this view is confirmed by Mr. Etchells himself, since he would have no hesitation in considering a beam in reinforced concrete as being free upon its supports, even if it were resting upon another beam or a pillar, on condition that the bending moment at the middle should be taken equal to $\frac{WL}{8}$, but it is to be noticed that for greater safety he advises in this case to provide at the points of support a few small bars in the upper portion of the beam.

It would appear to me that, if Mr. Etchells is willing to accept this method, he does not differ very much in opinion from those who think, like myself, that the safety of a beam is not impaired by adopting $\frac{WL}{10}$ in the middle and $-\frac{WL}{40}$ at the supports, or any other similar assumption, on condition, of course, that as far as the middle of the beam is concerned, we always remain above $\frac{WL}{12}$.

To terminate the discussion, I wish to explain the formula which I attribute to Rankine and which I mentioned at the end of my paper. This is also in answer to Professor Adams's remarks.

This formula is—

$$c_1 = \frac{c}{1 + a\,h^2 \times \frac{A}{I}}$$

in which c_1 is the stress of the material of the post in order to take into account column flexure, a is a numerical co-efficient equal to $\frac{c}{8E}$, c is the maximum stress of the material in compression, namely, 600 lbs. for the concrete, h is the height of the post, A the section of the post, and I its moment of inertia.

We have—

$$a = \frac{c}{8E} = \frac{c}{16{,}000{,}000}$$

A is equal to b^2

I is equal to $\frac{b^4}{12}$

If we neglect the steel bars, which we have a right to do since we are considering the stress of the concrete, by substituting in the preceding equation we have—

$$c_1 = \frac{c}{1 + \frac{12c}{16{,}000{,}000} \times \frac{h^2}{b^2}}$$

or else—

(1) $$c_1 = \frac{c}{1 + \frac{c}{10{,}000{,}000} \times 7{\cdot}5 - \left(\frac{h}{b}\right)^2}$$

This formula applied to the various values of $\frac{h}{b}$ allows us to calculate the working stress c_1 for $\frac{h}{b} = 15$. For instance, we would have—

$$c_1 = \frac{600}{1 + 0{\cdot}00006 \times 7{\cdot}5 \times 225} = 546 \text{ lbs.}$$

In my opinion, when the transverse reinforcement is not taken into account in the calculation of a post, the above formula could be adopted, in order to make the construction safer, instead of the formula given in the Rules of the R.I.B.A. or in the proposed Rules of the London County Council.

I regret that, owing to the length of the debate, it has not been possible for me to answer individually the remarks of the other members.

THE CHAIRMAN (Sir HENRY TANNER), in closing the meeting, said :— Monsieur Béhar fell into a slight error with regard to Wimpole Street and Manor Gardens, Holloway. Mr. Wager was the architect of these two buildings, I had nothing to do with them.

The meeting then terminated.

MR. ETCHELLS has forwarded the following contribution to the discussion, as the time did not permit of a full discussion of all the points involved :—

SIR,—The pressure of time and the lateness of the hour prevented the full development of my arguments in respect of the true bending moments of beams. The verbal discussion represents but a part of the case.

Mr. Béhar, in the course of his remarks, stated that "if the total length of the twelve spans had been divided up into groups of three beams the greatest moments on the supports would have been $-\frac{WL}{10}$ and that in continuous beams it is necessary to provide at the points of support a moment greater than $-\frac{WL}{12}$." I find myself in agreement with him here, because here he is in agreement with the laws of mathematics and mechanics, on which I take my stand.

Again, I should like to support Mr. Béhar's reply when he stated that by reason of the assumptions which we have to make in respect of continuity we have to apply at all the points of support the greatest bending moment which we have found for one of the supports, and this moment is always greater than $-\frac{WL}{12}$. As to the strength of brackets, it should be sufficient for me to say that I see no objection to

them, provided that the restraining couple is sufficient *and constant—i.e.*, the restraining should not depend upon the accidental presence or absence of a load on some adjoining bay. Mr. Béhar draws my attention to the Prussian Regulations and their reference to tension in the concrete. In reply, I should like to point out that the particular question under discussion is the true bending moment of beams, and not the hypothetical resistance moments ; but Mr. Béhar does well to point out that there are qualifications and modifying conditions accompanying this most stringent regulation as to a bending moment of $-\frac{WL}{8}$ over a support in lieu of the more usual $-\frac{WL}{12}$.

Might I now draw *his* attention to a further fact in respect of the stringent Prussian Code—viz., that when the tension in the concrete *is* allowed the stress on the steel would appear to be limited to 2,400 lbs. per square inch instead of the 16,000 common to British practice. How is this for stringency? To draw my attention to the omission affords me an opportunity of stating the other qualifications. Prussian Code, Chapter D, Section 16, Subsection 2 states *inter alia* that the tensile stress is not to be assumed greater than one-tenth of the ultimate compressive stress. Let us take a British concrete with an ultimate compressive strength of 2,400 lbs. per square inch at three months. The ultimate tensile strength would then be 2,400 10 = 240 lbs. per square inch. Subsection 2 of Section 16 states that two-thirds of the tensile strength may be allowed. In our case $\frac{2}{3}$ of 240 would give 160 lbs. tension. Chapter C., Section 15, Subsection 1 (of the Prussian Code) gives the modular ratio as 15. Therefore the stress on the tensile reinforcement embedded in concrete in tension would be $15 \times 160 = 2,400$ lbs. per square inch, not 16,000. I thank Mr. Béhar for affording me the opportunity of showing the real stringency of this particular Code. In the foregoing I have taken a British concrete, but if I took the German concrete the stress in the steel would be lower still.

Now, may I add qualification to qualification and point out that Mr. Béhar's remarks appear to assume

that the Prussians *always* allow the concrete to take tensile stresses, whilst the fact is that Section 15, Subsection 2 states that "The stresses in any section of a body under flexure are to be computed on the assumption that the reinforcement *carries all the tension*. Tensile stresses on the concrete are only allowed in buildings or members exposed to the weather, to dampness, to smoke, gases, and similar deleterious influences, where it must be shown that *cracks will not occur* from the tensile stress to which the concrete is subjected. I now, sir, deliberately reaffirm that the Prussian Code is more stringent than British practice. I refer you to the Codes themselves. I know the objections and the qualifications and the limitations; but when I present a *précis* of a foreign code that *précis* is a true mirror of the original, although every detail may not be elaborated. The suggestion has been made that for a uniformly distributed load the bending moment at the one support plus the bending moment at the centre should equal $\frac{WL}{8}$. It is suggested that anything contrary to this is contrary to the laws of mechanics. Now, the laws of mechanics is a very wide term. It is quite true that at the particular second when the end moment is $\frac{WL}{12}$ the centre moment is probably only about $\frac{WL}{24}$, but the laws of mechanics deal with moving loads, with rolling loads, and central bays loaded and adjoining bays unloaded. The laws of mechanics deal with diagrams of maximum bending moment for any position of a moving load. They deal with problems of an unfavourable disposition of a static load. They deal with questions of an envelope of bending-moment diagrams. They deal with influence lines, a method of dealing with maximum moments which is used by progressive railway engineers, but is almost unheard of among builders. The laws of mechanics cover something more than the static and constant bending moment of a uniform load glued to a beam for ever. Let my friend the busy builder put his centre moments at not less than his end moments. Let his end moments be arrived at by the simplest theory, and then he can leave all this erudition to the professors; and "he will have built better than he knew."

TWENTY-SIXTH ORDINARY GENERAL MEETING

THURSDAY, APRIL 25, 1912

THE TWENTY-SIXTH ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held in the Lecture Hall at Denison House, 296, Vauxhall Bridge Road, London, S.W., on Thursday, April 25, 1912, at 8 p.m.,

PROFESSOR HENRY ADAMS, M.Inst.C.E., M.I. Mech.E., M.C.I., etc., in the Chair.

MR. A. ALBAN H. SCOTT, M.S.A., M.C.I. (Hon. Secretary of Tests Standing Committee) :—In the unavoidable absence of Mr. Kirkaldy, the Chairman of this Committee, I have pleasure in putting before you the Interim Report of the Tests Standing Committee on the "Testing of Concrete, Reinforced Concrete, and Materials Employed Therein" (which report was published on pp. 265-70 of Volume III. of the TRANSACTIONS) and the following further report :—

REPORT OF THE TESTS STANDING COMMITTEE ON THE TESTING OF REINFORCED CONCRETE STRUCTURES ON COMPLETION.

It is frequently specified that test loads should be applied to finished structures of reinforced concrete shortly after completion. It should be recognised, however, that such tests should in no wise reduce the care to be exercised in the supervision of the work by those responsible. Since the test loads are generally applied only to specific parts of the work, such tests do not necessarily prove that the work has been properly executed either in whole or in part.

The test load should not be applied to any part until the expiry of 90 days from the last day of laying the concrete.

The deflection of beams under a test equal to the full working load for which the beams were designed should not exceed 1/1000th of the span.

In order to impose the full load upon a floor or roof beam under test the two bays of floor or roof adjoining require to be loaded all over, otherwise a considerable portion of the load is transmitted to the adjoining beams and the full load does not come upon the beam under test.

Not more than the superimposed load for which the beam has been designed, plus 50 per cent., should be applied as a test load.

When test loads are applied the materials used for loading should be put on in such a manner that no arching action whatever can take place, otherwise incorrect results will be obtained.

If systematic and thorough supervision be given by the professional adviser during course of construction the application of test loads to the finished structure is not so necessary.

Test cubes, if kept in an even temperature, which should be the same as that specified for cement briquettes, form a means of gauging under standard conditions the resistance to thrusting, and cubes kept in the open air will give the values for the concrete in actual practice. The results of these two sets of tests will be helpful in determining at what age the work is strong enough to sustain the loads.

I think I am right in saying that this Committee has held practically more meetings than any of the other Committees of this Institute, considering the time it has been in active operation.

DISCUSSION.

MR. MORGAN E. YEATMAN, M.A., M.Inst.C.E., M.Am.Soc.C.E., M.C.I. :—I have not much to contribute, as I have not had an opportunity of making a study of the Report till I came into the room, and I have not gone specially into the question of testing. But there are many points which it will be valuable to have discussion upon. I know the question of the proportion of water has always been a difficulty, and I think the Committee are probably wise in concluding that it is impossible to prescribe numerically the pro-

portion of water to be used. It must be judged by the conditions and the results in mixing.

In the question of the grading of the materials I think it is very valuable to have the materials measured or tested in the manner prescribed, to see what proportion there is of all the different sizes and what proportion of voids each size leaves. But I do not think it is desirable to use materials of uniform sizes. I think the different proportions should be mixed for this reason, namely, that a uniform material, that is to say, a material in which all the particles are about the same size, will leave an amount of voids ranging from 30 to 50 per cent., or 45 per cent. (sometimes it comes up to near 50 per cent.), so that you cannot secure having the voids in that broken stone filled unless you have at least half its amount of sand. And you cannot secure the voids in that sand being filled by cement unless you have cement to at least half the amount of the sand, that is, if the broken stone and the sand are respectively of uniform size. But if the sand consists of particles of a good many different sizes, then the smaller particles will fill up some of the voids between the larger ones, and it will not require so much cement to fill up the ultimate ones —in fact, it will be found that in material where the particles consist of a lot of different sizes mixed, the total amount of voids will be a good deal less than if all the sizes are the same. In specifying mixtures for concrete that fact should be taken into account, and in order to know how to deal with your materials it is very valuable to know of what different sizes they are composed, and in what proportions those sizes are present, which, I think, is provided for.

In the second Report, the time after the conclusion of the work before a test can be safely applied is very wisely specified. I have heard of tests being applied a very short time after the work was set, which was very risky, as such a proceeding is liable to break down a structure whose strength would ultimately have become all that was needed. Ninety days is, I think, a wise provision.

Mr. WILLIAM G. KIRKALDY, Assoc.M.Inst.C.E., M.C.I. :—I did not come prepared to speak on this Report ; I was more interested to hear any points in

discussion that were raised, but I might be allowed to refer to Mr. Yeatman's point, which I thought the Report covered. Our view was it coincided exactly with Mr. Yeatman's comments, that the sand should contain as many different sizes as possible, so as to have as few voids as possible. The proposal for taking the voids separately was really to find out whether there was a preponderance of large grade in the sand or a preponderance of fine stuff ; the idea was that we should not have uniform sand, but to attack the question by finding out what the proportions were, to give a chance then to add any more of a certain size to make up any deficiency. If the sand ran too fine, with no coarse grade, there would be a chance to correct that. Certainly it is very desirable to get the size as varied as possible from the coarse down to the fine. That makes a denser concrete, and, of course, better work and a much higher physical strength too. The crushing strength is in very direct relation to the density of concrete ; when there are fewer voids you make it better. And, of course, it is economy in the cement as well, as it is wasteful to use cement for filling cavities, as used to be done in the old days before men studied concrete questions as they have done recently.

I think, personally, with regard to the question of testing cubes it is rather desirable to have your data in, because some men may argue that ninety days seems a long time. But I think in this Report we may as well put forward what we think the best practice, and then any particular man, if he is tied for time, must use his own judgment. Personally, I think if you put the test on a structure too soon you may be doing harm. If the supervision has been close throughout on the job, that really ought to keep you right without the test load. But if you wish a test load, by all means make it on as late a date as you can ; do not put it on the work when it is "green," or you may be seriously distressing it.

I can assure the meeting that very great consideration was given to the Report by the members of the Committee, so as to try and cover all the ground. Of course, we aim high. Some men may think the tests are more complete than are necessary, but they

can always be cut down. The tendency in practice is to have fewer tests, but we have started out to give a programme of what we think would be advisable.

Mr. D. B. Butler, Assoc.M.Inst.C.E., F.C.S., M.C.I. :—I am somewhat in the position of Mr. Kirkaldy, since I am a member of the Tests Standing Committee, and therefore I am criticising what is partly my own work. At the same time I may say this, that the Report in print does not appear quite the same as it did in draft, which is frequently the case.

Referring to page 260, where the comparative tests are given between British standard sand and fine stone crushings, British standard sand, as we all know, is sand between $\frac{1}{20}$th and $\frac{1}{30}$th in. diameter—that is to say, it would pass a $\frac{1}{20}$th in. sieve, but would be retained on a $\frac{1}{30}$th in. sieve, whereas the fine sand from crushing all passed a $\frac{1}{30}$th in. sieve, and therefore it is very much finer than the standard sand, and consequently it could not be expected to give such good results. Since the Report suggests that all sand which passes a $\frac{1}{50}$th in. sieve be rejected, I think it would have been more interesting if, with these comparative tests between the fine sand and the standard sand, all sand passing a $\frac{1}{50}$th in. sieve had been eliminated from the fine sand.

Referring next to page 268, paragraph (*g*), the Report says there :—

> "In all cases specimen pieces shall be made in metal moulds, and the concrete worked in by punning and tamping and afterwards gently rammed."

I am a little doubtful what the exact definition of "punning" and "tamping" is. I always thought both were a kind of ramming, and if so the Report recommends that "the concrete shall be worked in by ramming and ramming and afterwards gently rammed." (Laughter.)

Mr. Kirkaldy made one point as to the tests of concrete and suggested them being fewer. I think there is a good deal in that point, because I am afraid, if all these tests which are mentioned were carried out, with every load or delivery of aggregate, it would be extremely necessary to put in force paragraph 23

of the Report, by which the cost of testing should be provided for in the contract.

Perhaps, gentlemen, I am more or less speaking against myself, since my own business, as most of those present are aware, is that of testing. At the same time, I do not think one benefits in the long run by making the tests cost too much.

What struck me more particularly is what is stated on page 268 in the bottom paragraph, where it suggests that the voids should be ascertained of (1) the whole and (2) of each separate grading. Surely the latter is carrying it too far. Again, in the next paragraph (*c*) The proportion of each grading to the whole, (*e*) The specific gravity of the coarse material and sand, (*b*) The exact dimensions of specimen cubes, (*c*) The weight per cubic foot of all specimens immediately before testing. Now, much of this seems to me to be needless expense, and I personally should not like to recommend a client to undertake all that. The same remarks apply, more or less, to the dates at which the cubes should be tested. I see the minimum tests suggested are from seven to twelve months. Well now, surely if one is to wait twelve months before one gets a final test the work has all been done, good or bad, and it cannot be altered. (Hear, hear.) It seems to me that anything beyond a twenty-eight days' test for control purposes is unnecessary. It may be useful for research and for reference afterwards, but for control purposes surely anything after twenty-eight days is not of much use. The same remark applies to the medium tests, which are carried up to two years, and the maximum tests, which extend to five years. Anything from two or three months up to five or six years is surely of value only for research purposes and cannot control the quality of the concrete.

MR. A. O. TRECHMANN, F.C.S., M.C.I. :—I did not expect to be called upon to speak this evening. I am not a member of the Committee and have not seen the Report before entering the room. It is, however, extremely interesting.

It seems to me an excellent thing that the testing of concrete should be put upon a proper basis. The testing of cement in the past has been, in my opinion, not altogether satisfactory.

I might say that personally I do not see the object of testing cement in a neat state. I take it that cement is purchased as a cementitious material, and it is its cementitious value that you want to arrive at, and you do not arrive at that by testing a cement neat. I might express my meaning in this way: if one wished to test the value of a glue, one would never dream of making a test block of it and applying the tensile strain test, you would want to test the amount of adhesion acquired by the glue. I think the Germans are quite right to have eliminated the neat test entirely.

I am a believer in the crushing test, and think it ought to be applied systematically. I have made a good many crushing tests for the purpose of comparison with the tensile test, and the results are very interesting.

Mr. R. N. SINCLAIR, M.C.I.:—Mr. Chairman, I find in the first page of the Report that pit gravel is included in the coarse material. I would like to ask if the Committee considered the advisability or otherwise of thoroughly examining this pit gravel, and, if necessary, washing it before it is used. One knows the loam and clayey matters that naturally accompany pit gravel, and I think in the majority of cases it is not good enough to simply take the gravel as it rises and use it for concrete. It is recognised that dredged ballast contains the minimum amount of foreign matter and often can be used right away, but this, of course, is not always available.

Coming to the question of sand, on page 260, clause number 8, I am inclined to think that so far as sea sand is concerned, confining oneself to a screen having apertures of $\frac{1}{50}$th of an inch square it would be found that practically little would be retained.

As to the question of grading the coarse material. Referring to a remark made by the first gentleman who spoke this evening, the provision in the report of meshes, the first mesh being $\frac{3}{4}$ of an inch by $\frac{3}{4}$ of an inch, the retaining one $\frac{1}{4}$ by $\frac{1}{4}$ of an inch, this seems quite satisfactory, and I cannot see that anything better could be provided.

Coming to page 267, I should like to ask if the Committee have made up their minds that sea water

is not the water to use, and that fresh water is essential?

The Committee apparently do not recommend that one should specify the proportions of water to be used in cubes which are made for testing purposes. It seems to me that using a standard sand and a standard cement it is quite practicable, however, to do so.

Coming to page 268, clause 21*g*, this is a question which has already been touched upon. I had myself put a cross against that when I saw the paper. Personally, I do not quite understand it. One realises in practice that a lot depends upon how much "punning," "tamping," and "gently ramming" is given; six men making six cubes may give six different results possibly out of the same gauging. I know it is a very difficult thing to say how much they shall do in the way of punning, etc., but I am afraid that a number of blocks made by one man who is not continually at it and knows exactly what to do will give varying results. I take it the harder it is "punned" and "tamped" and "rammed" the better the results.

There is another question, the last I would like to take up your time with, and that is this: Have the Committee considered the question as to how long a time should elapse after the concrete is deposited in the moulds or on the shuttering before that shuttering is removed? Of course, it is an important thing for a contractor in making up a tender, if he has a large area of floor and girders and beams to do; it is one of the first things he looks at, and naturally he wants to find out how much of the shuttering he can re-use to finish the job, or how long must elapse after the concrete is deposited before he can take the forms down. It is a question we are face to face with in actual practice, and I think it is one well worth the Committee's consideration.

Mr. PERCIVAL M. FRASER, A.R.I.B.A., M.C.I.:—As a member of this Committee I would just like to try and answer one or two of the queries which have been put forward. The last speaker has rather mistaken the function of this Committee. It has not, in any sense, been the drawing up of a specification of workmanship and materials; it is purely on questions of testing. An engineer has certain materials,

made and unmade, and he has to put them to test, and this Report lays down the general rules that govern his testing of those materials.

The last speaker mentioned the period for striking centering. That is not in any way a matter for this Committee to report on. I would like to draw his attention to the first words of the Report. This is an Interim Report, and a good many of the points which he has raised will no doubt be dealt with next session in a further Report.

He spoke, quite rightly, I think, as to testing for cleanliness. I think that is an omission from this Report. It is a very vital thing to get your sand and aggregate quite clean, but it is, at the same time, more or less a matter-of-fact thing which everybody, I think, would do. Of course, it is elementary, but there is no reason why it should not have some place, so great is its importance. I think that also applies to other questions of a like nature—namely, the sharpness of the sand. But, as I said before, we do not lay down here a general specification of materials.

It is often said that fine stuff in sand is no detriment to the sand, but I think the Committee are wise in fixing the minimum size of $\frac{1}{50}$th in. by $\frac{1}{50}$th in. In strict theory, a little below that size might be efficacious ; but the danger is that you may get a great deal below that size, which is distinctly detrimental.

With regard to determining the amount of water, the point is not to be laid down in hard-and-fast and dogmatic rules. Of course, the amount of water should be determined, but it should be determined by actual practice on one's work. One should decide, at the first go-off, what amount of water should be used and see it is carried out. There is only one way of determining that, and that is by an actual mixing.

With regard to the amount of water to be used, that, again, is not a function of this Committee to decide. It was very exhaustively dealt with by a Special Committee of this Institute.

On page 268, section 21, sub-section (*e*) it says :—

> "All laboratory-made test cubes shall be made, as far as possible, on practical lines . . ."

But there is a value in a purely laboratory test. It shows the acme of strength which can be obtained

by those materials if they are really mixed on scientific lines. I do not care for laboratory-made tests unless they are frankly made for that purpose.

With regard to paragraph (*g*), Mr. Butler says it reads, in effect, "ramming and ramming and afterwards gently rammed." (Laughter.) There was a fairly long discussion on that, and I think the Report would be benefited if a definition of those words were inserted—that is, the Committee's reading of those words. In my mind, there is a very great difference between "punning" and "tamping" and "ramming." "Punning" might be described as "poking," "tamping" as "slapping," and "ramming" as "punching" (laughter); "punning" is purely a "poking" action, "tamping" is a gentle patting to round off into position and level up, and "ramming" is to force the mass to consolidate purely and simply.

The seven days' test is not usual for concrete. Most seem to think that fourteen days is the first valuable period at which you can test, or even twenty-eight, but I think a seven days' test is absolutely essential. Reinforced concrete work in these days is generally rushed through pretty quickly; we want to find out equally quickly what kind of material we are dealing with.

A gentleman suggested the elimination of neat tests of cement, but I think that is going a trifle far. We know that the tensile strength of neat cement is, say, 750 lbs. to the inch; we have learned by indirect experiment the practical result we are likely to get from a neat cement which stands such a tensile strength, and until we have educated ourselves up a little more I do not quite think we ought to drop it.

Mr. Butler rather criticised his own Report, and if we amend this Report to Mr. Butler's ideas we shall have a Minority Report, which is very valuable in a way. He thinks that testing each grade of aggregate and sand for voids is going too far, but in view of the purely nominal cost of measuring for voids—the total cost on each sample being about 2s. 6d. for all grades—it would not seem to be doing too much to test for voids from a bulk which will represent anything up to 10,000 yards or more.

Mr. BUTLER :—Might I point out the variations in the delivery each time?

Mr. FRASER :—No, there should be no such variation. If you are not satisfied you are getting a uniform ballast you had far better condemn it.

Mr. J. B. TRAVERS SOLLY, Assoc.M.Inst.C.E., M.C.I. :—With reference to the size of sand, I understand that this Report is not supposed to deal with materials used in concrete, but only with the question of testing the materials. But still the Committee have made the remark that it is important that all sand that is not retained on an aperture of $\frac{1}{50}$th in. × $\frac{1}{50}$th in. should be rejected. Well, concrete work is not all done in England, and in some places it is very difficult to get the carefully graded sand that is advised by the Committee. And with reference to that, I would like to mention that in some cases it might be better to use a sand that has a comparatively large proportion of fine dust than to use a drift sand with rounded edges. I had the opportunity of testing mortar under those conditions. The mortar was 1 cement, 2 sand. I had drift sand which was very rounded, and I had crushed sand which had a very large amount of flour. The briquettes were tested at seven and fourteen days, and I think I had three briquettes for each test. With ordinary mixing, starting with drift sand (that is, the rounded edged sand) and cement, and from that to the crushed sand containing flour, with ordinary mixing, at seven days I got an increase of 29 per cent. in strength—tensile, of course. With the same crushed sand, using more water and mixing it very thoroughly, I got an increase of 69 per cent. At fourteen days I got similar increases of 20 per cent. and 34 per cent., and I attributed it entirely to the fact that the crushed sand was sharp-edged sand, whereas the drift sand had no sharp edges. I think in every case the quality of the sand can be very easily judged under a magnifying-glass, and that ought to be taken into consideration in connection with the question of passing a sand that has fine grading. With reference to the testing of briquettes, or rather the condition in which the briquettes should be kept, I see here it is specified on page 270 that all specimens shall be kept in air after mixing and slightly damp for the first seven days.

I may be behind in date ; I did not know that that was the usual system. Up to the last time I was doing any testing we covered the briquettes with a damp cloth for twenty-four hours, then took them out of the moulds and placed them in water, and they were kept in water for the six days, making seven days in all, and then tested. I am not singular in that practice, because I had lately an opportunity of hearing a paper read dealing with an engineering work upon which very large quantities of cement had been used. The author particularly drew attention to the fact that the briquettes were kept in water for seven days, and his experience was that the tensile strength of those briquettes varied very much according to the length of time that they had been left out of the water before testing. As he said, while in the laboratory everything could be done more correctly, according to rule, on the works sometimes it is not quite so easy, and on taking briquettes which had been kept out of water half an hour up to twelve hours before they were tested, he found a very great drop in their strength. In one case, at any rate, there was a loss of 300 lbs. to the square inch in the tensile strength of the briquette that had been left out of water for twelve hours, and he suggested that in all testing the rule should be laid down, to obtain uniformity, that the briquettes should be tested within half an hour of the time they are taken out of water.

Mr. ARTHUR WILLIAM BUNGARD, Licentiate R.I.B.A., M.C.I. :—I do not intend to discuss the Report, but may I ask one or two questions? In the first place I find in the Report that the tensile strength of the steel required is given, but I do not find any strength mentioned as to crushing, or the tensile strength of the concrete. I do not know whether the Committee have left that out accidentally, or did not intend giving it. If they give it for the steel, why not for the concrete?

In the second place, with regard to the cubes. The actual work will be done by labourers, and it seems to me that the six cubes should be made on the works, and the tests should be made on those cubes and not on laboratory-made cubes at all. You would first find out what the test is required in the laboratory, and

then see that the other cubes are made on the job by the men who will lay the stuff, and only have those particular cubes tested. I would ask, "Is it not possible for the result of the test on the laboratory-made blocks to be far higher than on those which are made by the navvy?"

With regard to paragraph 23 on page 270, "The Committee is of opinion that for the purpose of providing for the cost of testing a provisional sum should be included in all contracts where such testing will be required, this being the most satisfactory and fairest way to all parties concerned."

I think that the builder would allow for that. If he were told that he had to provide for tests, would he not allow for that in his tender?

Mr. KIRKALDY :—The speaker before last was doubtless thinking of the ordinary tensile briquettes of cement. In the last page of the Report, the Committee are referring entirely to concrete samples being kept in air. The damping of concrete cubes is to prevent them drying out prematurely. They should be kept damped for the first few days, but it does not refer to the briquette testing for the quality of the cement ; such briquettes are universally kept in water until time of testing.

Mr. BUTLER :—It does not differentiate.

Mr. KIRKALDY :—I think I am quite right in saying that it was concrete we were dealing with in that part of the Report. It is all under clause 22.

I am sure the discussion to-night will be very useful to the Committee that are considering these points.

I may say points have been very fully discussed in Committee, but it is always interesting to get outside views. The men outside are apt to raise points that we may have forgotten. I look forward with interest to have these thrashed out again ; no doubt the Report will be made clearer from that.

Mr. YEATMAN :—Might I be allowed to mention one point I omitted before, that is, whether clause 18 and 18*a* on page 268, providing for a large percentage of elongation or contraction of area at fracture, do not practically bar out the use of a higher tensile steel which would stand more than 60,000 lbs. per square inch,

but would not elongate so much as the figures given. I understand that tests on twisted square bars, even though they are made of steel of about that quality, show that the twisted bars have a considerably higher ultimate strength, and a very much higher yield point. They will stand about 60,000 lbs. before showing much elongation, but I do not think they will extend 25 per cent. before fracture ; but they make a very good material for reinforcement, and can be safely subjected, I think, to a higher strain than the ordinary medium steel bars.

Mr. GEORGE S. ROBERTS, M.C.I. :—There are two points I should like to raise on the Interim Report.

We are anxious that we should know as much about the materials we have to use in concrete construction, and it is only right that we should do so, but reading over this Report I think, as another speaker has already mentioned, that unless we are careful we shall hinder and not promote the interests of the subject.

I take it we are all here to push forward this method of construction, and I think it is one of the best and cheapest forms of construction, but if we are going to frighten people into thinking that unless everything is perfect they will have no faith in this method, and it will also make the cost nearly prohibitive.

Speaking as a contractor, the amount of money that one would have to lay out in plant, to enable the suggested tests to be carried out in actual work, would, I feel sure, make it impossible to get the work out at a reasonable figure, and if it is to be more costly than another form of construction, we are losing one of the inducements we can hold out to clients.

By all means give us as much knowledge as you possibly can, so that we can carry out the work efficiently and well, and know that when it is finished it will stand, but do not harass us with unnecessary testing, which does no good, and only increases the cost. The whole crux of the question is to employ men who thoroughly understand this work, and with reasonable supervision there is not likely to be much worry.

The suggestion of a provisional amount for testing is a good thing, but will clients agree to it? Will

not they say the contractors must see to this themselves?

MR. TRECHMANN :—The question of the quality and the size of the sand used for concrete has been raised. The cleanness of sand is, of course, absolutely essential, and I think some test ought to be indicated by which the suitability of the sand, its freedom from loam, etc., should be determined ; and, secondly, as to the size of the sand. It appears to me that in preparing a Report of this kind, one is rather apt to assume that every kind of good material is available, wherever work to be carried out may be situated. But, supposing that sea sand is the only sand obtainable, it is not improbable, as one of the speakers suggested, that all or nearly all of it would pass through the $\frac{1}{50}$th by $\frac{1}{50}$th inch sieve. Now, if such a sand *must* be used, would it not be as well to specify the increased quantity of cement to be used with it, to make up for the increased number of particles and surface area as compared to a standard sand?

THE CHAIRMAN (Professor ADAMS) :—In order that the work may be reliable and accord with the calculations, it is necessary to make careful and uniform tests of the materials as actually employed, but it appears to me that some of the tests proposed are more adapted for purposes of research than for the stability of the work. Remarks have been made about pit gravel ; pit gravel was once either river gravel or sea gravel, and the difference from exposed gravel in nearly all cases is that there is a certain amount of iron oxide attached to it, and often loam, and when pit gravel is used, it is specially necessary to see that it is clean.

On the second page, the little table at the bottom shows in a very striking way, I think, the necessity for excluding all dust from the work. The dust, in a sense, goes to fill up all the interstices, but in order that it may usefully fill them up, every particle of dust must be encased in fine cement, therefore a greater proportion of cement is necessitated.

At the International Congress of Architects some few years ago, I called attention to the desirability of grading the larger aggregate, reducing the maximum

size down to 1 in. or $\frac{3}{4}$ in., and giving all sizes in between down to $\frac{1}{4}$ in. At that time it was customary to only specify the larger size, whatever that might be, sometimes as large as $1\frac{1}{2}$ in., and firms even advertised their broken brick of uniform size as if that was a great recommendation for it. Now, we find all specifications practically state that the material is to be graded.

With regard to the question of grading the sand, I do not think that is so important as grading the larger material, but it enables us to use some larger particles of sand than has formerly been the custom. On the diagram, one matter struck me as rather curious, "Sea-sand (on shore for twenty-six years)." I should like to know from what evidence that age is assigned. (Laughter.)

Mr. ALBAN SCOTT :—Before I reply, Mr. Chairman, it is quite a simple matter, although it has caused laughter. This sea-sand was carted twenty-six years previously by known facts right inland from the sea, and it has been on a heap for that number of years, and we originally used it in a large water-tank, and these are the results of experiments made to ascertain the voids from that sea-sand actually used.

THE CHAIRMAN :—That puts it on quite a different basis. I thought the sand had been on the sea-shore for twenty-six years. It says, "(on shore for twenty-six years)," and that seemed very curious. It had left the sea for twenty-six years ; that is the explanation.

Mr. ALBAN SCOTT :—That is right.

THE CHAIRMAN :—I suppose all the salt was washed out of it by that time?

With regard to testing the steel, no rate of application is mentioned. It is as necessary, I think, in testing steel as in testing cement, to have a uniform rate of application.

With regard to the contraction of area, or the elongation, the tendency appears to be at the present time to prefer the test for contraction to that for elongation, possibly, to some extent, because there used to be at least three standards of length : $6\frac{1}{4}$ in.—that is, 100 16ths of an inch—8 in., and 10 in., and

then later some shorter lengths still were put in, so that the percentage of elongation would vary with each of those lengths, although it was the same identical material.

The "working-in" and "punning" and "tamping" are varieties of very useful processes, but I think possibly the Committee might be able to improve upon the wording they have adopted. The Committee recommend that a provisional sum should be included in all contracts for the cost of testing. That is a counsel of perfection. They give no idea of what that cost will be. If we could have verbally in the discussion some idea of the cost that these recommended tests would run to it might be useful. On a large contract there is no difficulty, as a rule, in getting the client to agree to the tests, but on a small contract it is really out of the question.

With regard to testing the finished structures, very little has been said about that in the discussion. I think it is open to grave risks. Suppose the structure is in such a condition as to need the test, then the greatest risk is caused, because you are straining parts beyond their elastic limits, we will say, or creating incipient cracks which do not fail at the time. Perhaps the point is clearer in the case of machinery. It came to me very forcibly some years ago, when the Home Office were formulating their Regulations for docks and riverside warehouses as to the care of chains and machinery for lifting. They argued that the machinery should be tested with the full load periodically, and that that would be satisfactory. I advised them that, in my opinion, that would be most unsatisfactory, because it would lead to this: A machine might be tested—we will say it is doing nothing but being tested—time after time with the full load until ultimately it would give way with the full load. But the time before that, when it was tested, it took the full load and did not fail, therefore it is no safeguard, and particularly in the case of crane chains. I have had a very large quantity of these through my hands, and the responsibility of those chains and the men working under them, and I was, from experience, always against the repeated testing of a chain by mechanical tests. My practice was to have

the chains periodically taken off, fired, annealed, and examined link by link, but not put under a mechanical test, and I believe that the examination in that way was a much greater safeguard than a mechanical test. And so with regard to testing the finished building. It is very much better to see that you have proper supervision, proper designs, and proper checking of those designs before the work goes in hand, than to rely upon any tests that you may make upon the finished work afterwards.

MR. A. ALBAN H. SCOTT :—Mr. Chairman and Gentlemen, I shall be glad if you will kindly take my reply as personal remarks and not in any way as the official reply of the Committee. During the course of the discussion it seemed very strange that no one raised objection or discussed the tests on steelwork. From this I think we are safe in concluding that you are all of opinion that tests on steelwork are highly desirable. We have had a good deal of criticism on the tests for the concrete. As there is a much larger human element employed in the making of finished concrete than there is in the making of steel there is more chance of defects in the finished concrete, and I think the Committee would be still working in the proper direction if the tests on concrete as suggested by them remain unmodified.

The proposed tests on steelwork in the Report are now accepted practically by every rolling-mill, always provided you give them good notice so that they can get proper billets from which to roll the metal to withstand the tests. I feel quite sure that very shortly every engineer and contractor will accept without hesitation the tests which we have suggested in this Report.

On March 8th I gave a paper on this subject at the Society of Architects, and one point I tried to make particularly was that at the present moment various official rules are taking 1,800 lbs. as the ultimate strength of concrete, and are taking 600 lbs. per square inch as a working load. Working to these loads, it is absolutely imperative that you should have the very best concrete, and if you are dealing in concrete at all, then you must have the very best or leave it alone altogether.

Dealing with the criticism on the question of grading aggregate and sand, we have had no difficulty at all in getting aggregate and sand graded to whatever proportion we wish, and it is quite a commercial product. This graded material must be obtained from crushers. The method of sifting Thames ballast and rejecting everything over the size required is a thing of the past. I feel quite sure that if concrete is not tested, and we only rely upon haphazard methods, we can very shortly anticipate disastrous failures in reinforced concrete work. We have had a few already, from what causes I will not enter into now; but we shall be certainly increasing our percentage of failures unless the actual concrete used in structures is more carefully watched and brought to a higher standard, unless the various rules, official and otherwise, are altered so that the present limiting value of 1,800 lbs. is reduced to at least 1,500 lbs. Concrete test cubes, properly taken and properly tested from the actual job, will not give such results as to justify 600 lbs. as the actual working stress. You will see from the Report of the Society of Architects' meeting my feelings on the matter as regards the testing of structures after completion. I think such tests are not only undesirable, but are inviting trouble. The testing suggested in the Report we have been discussing this evening seems to have frightened some of the members present, but this Report is put in the form of a model, and must of necessity aim at the ideal. When you come to consider the actual cost involved, it is not so serious as you would anticipate. On reinforced concrete work costing about £10,000 the tests suggested can be comfortably carried out, if properly arranged, for about £150, and I do not consider that such a small percentage on the cost of the work for testing is extravagant; but whether it is a high or low sum, as long as we use reinforced concrete work it is essential that it should be tested, and £150 is just as necessary and desirable as it is to have the centering for constructing the work.

Dealing generally with the question of concrete, the greatest trouble seems to be the extent of competition in prices, and it is not always desirable in reinforced concrete work to accept the lowest tender.

The question of safety of the building is much more important than the question of saving a few hundred pounds.

The cleanliness of gravel is extremely important, and some most extraordinary results have been obtained recently on tested samples. Up to April 8th we only had one or two samples tested, and about 7 per cent. of loam was the average result. Since that date we have conducted a series of tests, and we find that loam in gravel varies from 5 per cent. to 29 per cent. of its bulk in weight. Strange as it may sound, the material containing 29 per cent. of loamy matter looked perfectly clean.

Mr. Butler raised a serious question with regard to the table on page 260. That records the result of practical tests made very carefully to see the extreme effect of dust, and it did show that it had a very bad effect upon the finished material. Since that date we have had four more tests carried out on other dust, which have more than confirmed the conclusions arrived at in the case referred to.

One gentleman raised a question as to a certain shaped bar. I do not wish to continue to bring in any patent bar ; it is undesirable at this meeting, and I do not feel quite free to criticise it, but, at the same time, in any metal that is twisted, when it is twisted cold, the actual centre of the bar remains the same dead length as before twisting, whereas, taking a square bar, the corners considerably increase in length, and it is certainly a question yet to be determined what effect there is on metal so distorted.

Mr. BUTLER :—It gets very brittle.

Mr. ALBAN SCOTT :—Mr. Fraser dealt with some of Mr. Butler's criticism on item 22, but I would mention with regard to the exact dimensions of the concrete cube and the exact weight of same and minor points, so far as the cost is concerned, they are most important for the purpose of the test.

One gentleman discussed the question of the removal of centering. This does not come under this Committee's Report, but I would like to call special attention to the fact that the seven and fourteen days' tests on concrete cubes will materially help in determining at what age the work is strong enough to sustain loads

without such centering. The question of the proportion of water has also been raised, and if you refer to the Society of Architects' Journal for April, on pages 222-27 you will find particulars of a series of tests, one series of which is most particularly interesting. This was undertaken by Mr. Kirkaldy on sixty-four cubes, and it conclusively proved that the drier the concrete is and the more ramming or tamping it receives the better the results. This is confirmed by every other test which we have carried out, and, further, it must be borne in mind that the exact proportion of water in concrete must vary considerably, according to the nature of the concrete and sand, and also on the condition of the weather.

In conclusion, I would like to express my personal view that in the present stage of reinforced concrete there are many irresponsible contractors and designers taking the work in hand ; and in issuing such a Report as this Committee take upon themselves to do, it is better to err on the side of carefulness rather than to say, "Go ahead ; put in the concrete the same as you put the concrete around drains."

THE CHAIRMAN (Professor ADAMS) :—Gentlemen, I am sure it will be in accordance with your wishes that I should express the thanks of the meeting to the Tests Standing Committee for this Report, and particularly to Mr. Kirkaldy, the Chairman, and Mr. Alban Scott, the Honorary Secretary, because we all know that upon those two officials the work of the Committee chiefly falls. Mr. Alban Scott has also given us the extra advantage of reading the second Report to us to-night and replying upon the discussion. (Applause.)

The meeting then terminated.

The Tests Standing Committee, having subsequently reconsidered their reports in view of the foregoing discussion, make the following addenda :—

(1) The Committee cannot see their way to alter or amend Clause 9, and suggest that if sand smaller than will pass a $\frac{1}{50}$th in. by $\frac{1}{50}$th in. sieve be used that more cement should be employed.

(2) The Committee is of the opinion that compression tests on cubes are desirable ; if, however, it be considered that the cost involved in the least of their recommendations would be excessive for any particular job, then their recommendations of a series of tests should be carried out as far as possible.

THIRD ANNUAL GENERAL MEETING

THURSDAY, MAY 9, 1912

THE THIRD ANNUAL GENERAL MEETING of the CONCRETE INSTITUTE was held at Denison House, 296, Vauxhall Bridge Road, London, S.W., on Thursday, May 9, 1912, at 4.30 p.m.,

SIR HENRY TANNER, C.B., I.S.O., F.R.I.B.A., President, in the Chair.

The following were elected members of the Institute :—

CHRISTOPHER WILLIAM BALLENDEN, Johannesburg.
SPENCER EDWARDS, Barnstaple.
CECIL THOMAS LEWIS, Ilford, Essex.
HAROLD LINGARD, Madras, India.
PERCY J. PIKE, Assoc.R.San.Inst., M.Inst.San.E., Stud.Inst.Mun.E., Southend.
ARTHUR REGINALD SAGE, Assistant Principal of L.C.C. School of Building, Brixton, S.W.
IAN M. SUTHERLAND, Victoria, Australia.
ALLAN GRAHAM, A.R.I.B.A., London.

THE SECRETARY (Mr. H. KEMPTON DYSON) then read the Report of the Council as follows :—

REPORT OF COUNCIL FOR 1911-12 SESSION.

The Concrete Institute had on April 30, 1912, 881 Members, 24 Students, and 11 Special Subscribers.

The increase in membership from the foundation of the Institute is recorded in six monthly periods in the accompanying chart.

The Finances of the Institute are, as shown by the accompanying Balance Sheet, in a satisfactory condition.

The General Meetings and Visits are duly recorded from time to time in the TRANSACTIONS, and therefore are not included here. The thanks of the Institute are due to the authors of the papers and to those who acted as hosts on the occasions of the visits referred to.

The Council has in the past year been concerned with numerous technical and administrative matters.

One of the principal items occupying the attention of the Council and a Joint Committee of the Science and Reinforced Practice Standing Committees has been the consideration of the proposed Regulations made under the provisions of Section 23 of the London County Council (General Powers) Act, 1909, with respect to the construction of buildings wholly or partly of reinforced concrete. A draft of suggested Regulations was submitted by the Superintending Architect of the London County Council to the Institute for its consideration, and the action taken was recorded in the Annual Report for the 1910-11 Session. The 1909 Act referred to provides that the Concrete Institute, together with the Institution of Civil Engineers, the Royal Institute of British Architects, and the Surveyors' Institution, shall have notice of the Council's intention to apply to the Local Government Board for the allowance of any regulations as to the use of reinforced concrete in the county of London, and such notice was duly given at the beginning of December, 1911. The Institute's suggestions as to the amendment of these regulations have been sent to the Secretary of the Local Government Board and to the Superintending Architect of the London County Council, and in due course the Council of the Concrete Institute will be able to inform the members as to the outcome of such action.

In October, 1911, a proposal for widening the scope of the Institute was considered by the Council and referred to a Committee whose report was approved on March 14, 1912; an abstract of the report is appended. The members of the Committee are: Mr. E. F. Etchells (Chairman), Professor Henry Adams, Mr. Alexander Drew, Mr. Charles F. Marsh, Mr.

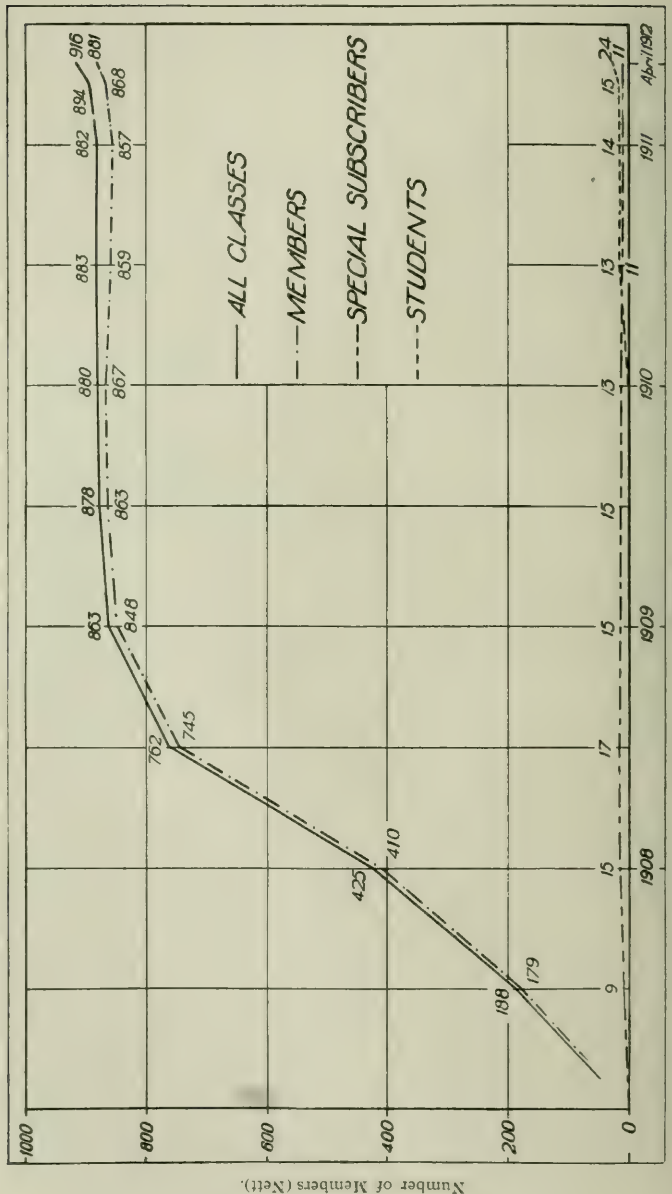


Chart showing growth of membership of Concrete Institute from foundation to April 30, 1912.

W. G. Perkins, Mr. Edwin O. Sachs, Mr. H. D. Searles-Wood, Mr. L. Serraillier, Sir Henry Tanner, and Mr. E. P. Wells.

A seal, medal die, and certificate of membership have been designed and engraved for the Institute by Mr. Cecil Thomas, and the certificates of membership have been issued to all the members who have paid their subscriptions for the current year.

The question of awarding a bronze medal for the best paper read in the previous session was decided by ballot among the members of Council, and as a result the medal has been awarded to Professor Beresford Pite, F.R.I.B.A., for his paper entitled "The Æsthetic Treatment of Concrete."

Sir Henry Tanner has been appointed delegate of the Concrete Institute at the Congress of the Royal Sanitary Institute to be held in June next.

The International Association of Road Congresses have asked the Institute to appoint delegates to the Third International Road Congress to be held in London in June, 1913, and delegates will be appointed after the Annual General Meeting has taken place.

The following Members of the Council resigned in the past year: Mr. William Dunn, Captain J. Gibson Fleming, Sir Douglas Fox, Mr. W. T. Hatch, Mr. W. H. Johnson, Mr. F. May, Sir William Preece, and Mr. Alexander Ross. The Council co-opted the following to fill some of the foregoing vacancies: Mr. H. Percy Boulnois, Mr. Alexander Drew, Mr. A. Alban H. Scott, and Mr. L. Serraillier.

In consequence of the resignation of Sir Douglas Fox and Sir William Preece as Vice-Presidents of the Institute and of the retirement of Sir William Mather, Mr. William Dunn, Mr. C. S. Meik, and Mr. F. E. Wentworth-Sheilds were appointed to the vacancies in November. Mr. William Dunn and Mr. Alexander Ross resigned as Vice-Presidents in March and Mr. H. Percy Boulnois and Mr. E. P. Wells were elected in their stead.

Sir Henry Tanner's term of office as President expiring in May, Mr. E. P. Wells was appointed President for the ensuing two years. The Council is pleased to record that Sir Henry Tanner will continue as a Member of Council in the capacity of

INCOME AND EXPENDITURE ACCOUNT.

Year Ending December 31, 1911.

Dr. | *Cr.*

INCOME.

	£ s. d.	£ s. d.
To Annual Subscriptions	797 6 11	
„ Special Subscriptions...	52 10 0	
„ Students' Subscriptions	7 7 0	
		857 3 11
To Sundry Receipts :—		
Various Receipts	2 19 5	
Interest on Deposit Account	3 18 9	
		6 18 2
		£864 2 1

EXPENDITURE.

	£ s. d.	£ s. d.
By Office Salaries	275 0 0	
„ Office Rent, Hire of Halls, Cleaning, Lighting, Heating	148 11 4	
„ Printing, Reporting, &c.	228 7 11	
„ Postage, Telegrams, &c.	60 14 5	
„ General Expenses	70 10 2	
„ Accountancy	11 11 0	
„ Stationery	18 0 0	
„ Books and Utensils	42 2 1	
		854 16 11
Balance :—		
Being Excess of Income over Expenditure		9 5 2
		£864 2 1

PROFIT AND LOSS ACCOUNT.

	£ s. d.
To Balance of Income and Expenditure Account brought down	9 5 2
„ *Balance* carried to Balance Sheet ...	4 15 5
	£14 0 7

	£ s. d.
By Amount written off Furniture for Depreciation	14 0 7
	£14 0 7

BALANCE SHEET.

Year Ending December 31, 1911.

Dr. | *Cr.*

LIABILITIES.

	£ s. d.	£ s. d.
To Subscriptions received in advance ...		39 18 0
,, Current Liabilities		161 4 5
,, SURPLUS:—		
As at 31st December, 1910	163 10 1	
Less Balance from Profit and Loss account	4 15 5	
		158 14 8
		£359 17 1

ASSETS.

	£ s. d.	£ s. d.
By FURNITURE:—		
As at 31st December, 1910	38 2 8	
Additions to date	102 3 9	
	140 6 5	
Less 10% Depreciation written off to Profit and Loss Account	14 0 7	
		126 5 10
,, CASH:—		
At Bankers, on Deposit	200 0 0	
At Bankers Current Account	30 8 11	
In hand	3 2 4	
		233 11 3
		£359 17 1

I report to the Members that I have obtained all the information and explanations that I have required, and that I have examined the above Balance Sheet dated 31st December, 1911, with the Books and Vouchers of the Concrete Institute. I certify that such Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Institute's affairs according to the best of my information and the explanations given me, and shown by such Books and Accounts.

(*Signed*) H. DENTON HARDWICKE, F.L.A.A.,
Certified Accountant.

April 4, 1912.

(*Signed*) HENRY TANNER,
President.

E. P. WELLS,
Chairman of Finance and General Purposes Committee.

H. KEMPTON DYSON,
Secretary.

a Past President and continue to give the Institute that help and guidance which has been so valuable in the past.

It has been decided that Chairmen of the various Committees shall be subject to annual election or re-election, and that the lists of members of the Standing Committees shall be revised after each annual election of Members of Council. It has been decided also that Chairmen of the Committees shall be *ex-officio* Members of the Finance and General Purposes Committee.

The First Annual Dinner of the Institute was well attended and passed off successfully. The attendances at the two days' Summer Meeting were not satisfactory, and it has not been thought advisable to hold similar meetings this year.

During the present Session a larger number of Meetings will have been held than in any previous Session, and next Session it is intended to resume the course of Educational Lectures to Students which were begun last Session. The work of the Institute is increasing, and it is hoped to extend the number of Meetings next year and that the subjects to be dealt with will be of more general interest by reason of the extension of the scope to cover structural engineering generally.

A Library is in process of formation at the Institute and a number of donations have been received, but the Council would welcome the presentation of books, papers, and other publications on the subject of structural engineering generally, the funds at present precluding any large purchase of such works. A catalogue of works in the Library will eventually be published and members will be enabled to borrow books.

The TRANSACTIONS will in future be issued quarterly and articles or notes from members will be welcomed for insertion therein. In order to meet the extra cost it is proposed to invite advertisements, and the assistance of members in this direction will be valuable.

The Finance and General Purposes Committee has held regular meetings preliminary to each Council Meeting, and the general results of their deliberations are recorded in the foregoing particulars of the work

of the Council during the year. Mr. H. D. Searles-Wood and Mr. G. C. Workman were appointed Members of the Finance and General Purposes Committee in June, 1911, in lieu of Mr. W. T. Hatch and Mr. L. Serraillier.

As regards the work of the Science Standing Committee, the Institution of Municipal and County Engineers requested the opinion of the Concrete Institute upon a Standard Specification for Concrete Flags which they proposed issuing and the Committee made a number of suggestions which the Institution has intimated will be considered in any revision they may make in the future of their Specification. The Standard Notation for calculations for reinforced concrete which was drafted by the Science Committee and approved by the Council continues to meet with favour and has been adopted by the Joint Committee on Reinforced Concrete appointed by the Royal Institute of British Architects in their Second Report and by the London County Council in their proposed regulations covering the erection of buildings of reinforced concrete in London. Authors of textbooks have also employed it and the American Joint Committee on Concrete and Reinforced Concrete have informed the Science Committee that they have the Notation under consideration with a view to its adoption in any further Report they may make. Professor Henry Adams and Mr. E. F. Etchells were appointed Chairman and Vice-Chairman respectively of the Science Standing Committee in June. Mr. F. E. Wentworth-Sheilds having resigned as Hon. Secretary of the Committee, Mr. H. K. G. Bamber was appointed in his stead. The Committee have the following matters under consideration :—

(1) Reinforced concrete piles.
(2) A chemical test for steel used in reinforced concrete.
(3) The standardisation of attachments or joints in reinforced concrete.
(4) The adhesion of or friction between concrete and steel.
(5) A standard notation for calculations in structural engineering generally.

(6) A standard specification for reinforced concrete work.
(7) The effect of sewage on concrete.
(8) The effect of oils and fats on concrete.

The Science Committee appointed the following as representatives of the Institute upon the Joint Committee on Loads on Highway Bridges which is conducted by the Concrete Institute: Professor Henry Adams, Mr. William Dunn, Mr. Charles F. Marsh, and Mr. C. S. Meik. The other members are as follows :—

John A. Brodie, M.Eng., Wh.Sc., M.Inst.C.E. A. E. Collins, M.Inst.C.E. J. W. Cockrill, M.Inst.C.E.	Representing the Institution of Municipal and County Engineers.
A. E. Prescott, M.R.San.I. Henry C. Adams, Assoc.M.Inst.C.E., A.M.I.Mech.E., A.M.I.E.E. H. C. H. Shenton, M.R.San.I.	Representing the Institution of Municipal Engineers.

The Joint Committee has had one meeting and has issued inquiry forms to municipal authorities and others soliciting information respecting the vehicles that have to be sustained in various parts of the country as a preliminary to drafting recommendations.

The Tests Standing Committee have issued reports on "The Testing of Concrete, Reinforced Concrete, and Materials Employed Therein" and "The Testing of Reinforced Concrete Structures on Completion." These have been discussed at Ordinary General Meetings of the Institute. The Committee have the following matters under consideration :—

(1) The effect upon steel of the presence of sulphur in aggregates.
(2) The grading of aggregates.
(3) The expansion and deterioration of concrete due to changes of atmospheric temperature.
(4) The effect of the use of sodium silicate on the surface of concrete as affecting reinforcing metal.
(5) The erratic results obtained by the Vicat needle in ascertaining the initial set of cement.

The Reinforced Concrete Practice Standing Committee have drafted reports on the subject of "The Standardisation of Drawings for Reinforced Concrete Work" and "The Consistency of Concrete," which have been discussed at Ordinary General Meetings of the Institute. The Committee have also had under consideration a reference of the Council for a report as to clauses in contracts for reinforced concrete work, but the Committee recommended the Council that they were of the opinion that the formulation of clauses in contracts was a legal matter, and the Committee did not feel they were capable of formulating such clauses. The Committee are still investigating :—

(1) Methods of treating the surface of concrete.
(2) Cracks due to the expansion and contraction of reinforced concrete.

APPENDIX.

ABSTRACT OF REPORT OF THE COMMITTEE APPOINTED TO CONSIDER THE WIDENED SCOPE OF THE CONCRETE INSTITUTE.

On October 26, 1911, a proposal for extending the scope of the Institute was considered by the Council.

After considerable discussion it was unanimously resolved that :—

"The Council do approve in principle the proposal for enlarging the scope of the Institute."

It was also unanimously resolved that a Committee be appointed :—

(*a*) To consider how the above Resolution could best be carried out.

(*b*) To take energetic steps to develop the Structural Engineering side of the widened scope.

The Committee of ten members of the Council was elected, and Mr. E. Fiander Etchells was appointed Chairman.

At a series of meetings it was resolved that :—

SCOPE.

(*a*) Clause 3 (1) of the present rules does not limit the scope of the Institute to concrete and rein-

forced concrete, but that the clause enables the Institute to deal with iron (including steel), bricks, gravel, sand, cements, and other structural materials and their application.

Definitions.

(*b*) For the purposes of the Institute, *Structural Engineering* be defined as that branch of Engineering which deals with the scientific design, the construction, and the erection of structures of all kinds in any material.

(*c*) *Structures* may be defined as those constructions which are subject principally to the laws of *Statics*, as opposed to those constructions which are subject principally to the laws of *Dynamics* and *Kinematics*, such as engines and machines.

Title.

(*d*) After very long discussion, the Committee came to the unanimous decision that the term " The Concrete Institute " should remain in the title, and that it should have the first place in the title and that a sub-title should be added, so that the full title and sub-title should be—

THE CONCRETE INSTITUTE,

AN INSTITUTION FOR STRUCTURAL ENGINEERS, ARCHITECTS, Etc.,

and that such description should be added to all documents wherever practicable.

Lectures and Examinations.

(*e*) An annual course of technical lectures on some branch of Structural Engineering be instituted.

(*f*) Examinations in Structural Engineering be held by the Institute once a year, to test the scientific or technical attainments of applicants for Studentship.

Subscriptions.

(*g*) An entrance fee of one guinea be required when the membership reaches one thousand.

TRANSACTIONS.

(*h*) TRANSACTIONS should be issued quarterly.

(*i*) Members should be requested to return the reports of discussions at meetings not later than seven days after receipt and that the following circular letter be sent to speakers :—

> "In order to facilitate publication of the TRANSACTIONS, early return of the enclosed report of your contribution to the discussion of the above-mentioned paper is requested. The Council have directed that reports which are not returned to the Institute within one week shall be published in the form shown."

(*j*) Members be hereby invited to submit a note as to suggested papers covering all branches of Structural Engineering.

(*k*) New books received should be reviewed in the TRANSACTIONS.

(*l*) A referendum be employed to ascertain the wishes of the members as to :—

1. The most convenient meeting-place.
2. The most suitable hour of meeting.

(*m*) The time is not yet ripe for any change of rules, but that the suggestions in this Report should be worked upon for twelve months as a trial.

The Committee desire to state that valuable information has been collected in connection with the revision of Rules, and this information will be filed for future reference, and is to some extent embodied in the Minutes of the Committee's proceedings.

DISCUSSION.

THE CHAIRMAN (Sir HENRY TANNER) :—In moving the adoption of this Report, there does not seem to be very much that I can add to the full statement which has been made, but there are two or three points which I should like to emphasise. So far as our membership goes, we are on the increase slightly. We have not gone back, which is a very great point. We have lost a great many members, but, on the other hand, on the balance there has been a slight advantage. I suppose, having regard to the

very large membership that we obtained at first, we ought to be satisfied with even making some slight progress.

Then, as to our finances, they are none too good, but still they are on the right side. I think we have been, perhaps, at an abnormal expense this last year in providing office furniture and other things, but now we are established there ought not to be that expense. We still have got some money on deposit, which is a very good feature.

The London County Council Regulations have occupied most of the members of the Council and the Sub-Committees. I think, however, that we have done very good service in what we have sent to the Local Government Board.

Then, as to the Scope, you will think probably that the Report of that Committee does not go very far, still a quiet commencement has been made, and we hope we are going in the right direction, and that we shall make the Institute of more extended interest to our members, and, therefore, we shall increase our numbers, at least that is our hope.

As to the Library, we have got very few books, and we should like as many members as possible to make us gifts of books. I daresay there are many members who would be very anxious to do that if they only knew what was wanted.

The Science Standing Committee, and the Tests Standing Committee, and the Reinforced Concrete Practice Standing Committee have all done useful work, and you will see, stated very clearly in the Report, what they have been engaged upon during last session, and I consider that we ought to be very thankful to those Committees for giving so much time and attention to the business.

We have dropped the educational lectures this session, but it is one of the proposals of the Committee on the Scope of the Institute that these should be resumed next session.

With these few observations, gentlemen, I propose that the Report be accepted by the meeting.

MR. EDWIN O. SACHS, V.P.C.I., F.R.S.Ed. :—I merely wish formally to second the Report. It contains much that will be of interest to the majority of

members who are far away, and which I trust they will read carefully. There is much that might well be made the subject of debate, but on an occasion like this we all wish to have an unanimous adoption of the Report, and thus a debate would be out of place. It is a great pleasure to me to be able to second it.

There is one paragraph in the Report, however, which I should like to particularly point to, and that is the second paragraph on page 6. I wish to call attention to the fact that we are losing our President, Sir Henry Tanner, and we will all agree that that is, I am sure, a very great loss. Sir Henry Tanner has steered this Institute through two years of very critical times. I think, to put it quite plainly, that Sir Henry Tanner held the Institute together, because the Institute when he started his presidency was only about three years old. It was a very young child, but was somewhat of a handful. It had all the ailments, as I think I once said before, that children are apt to get. But Sir Henry Tanner acted as nurse and doctor in one, and it grew to be robust if not larger in size under his treatment. Latterly the Institute has also made a spurt at growing, and thus when Sir Henry Tanner leaves the Chair it will fall to our friend, Mr. Wells, to see that this is no mere spurt but a regular growth.

I think it should be pointed out very plainly to what a very great extent we are indebted to Sir Henry Tanner for having guided us, and I take this opportunity of emphasising that point, as I understand that any remarks on the Report appear in the TRANSACTIONS, and our many members who are away in the Colonies will thus be informed of our views of the great services rendered by the retiring President. I have very much pleasure in seconding the adoption of the Report. (Applause.)

MR. LUCIEN SERRAILLIER, M.C.I. :—May I suggest, sir, that it might be desirable to delete the words "after considerable discussion" at the bottom of page 271, and state "that it was unanimously resolved that the Council do approve in principle the proposal for enlarging the scope of the Institute." I think there was no doubt on that Committee that it would be desirable to enlarge the scope, so that to say "after considerable discussion" would imply that there was a

difference of opinion on that point. I think the discussion took place on the way in which the scope should be widened. Then, on page 158, do you think it is desirable to ask the assistance of members in canvassing for advertisements for the TRANSACTIONS? Would it not be better to leave that out?

THE CHAIRMAN (Sir HENRY TANNER):—The mere fact it has been put in answers its purpose.

Does anybody second these two propositions?

After a pause:—

THE CHAIRMAN (Sir HENRY TANNER):—You have no seconder.

MR. H. PERCY BOULNOIS, M.Inst.C.E., V.P.C.I.:—Speaking to the Report, Mr. Chairman, as a new member of this Institute and my first appearance at any of your meetings, I should like to support the adoption of this Report and to congratulate the Council upon the work which they have done. There are one or two questions I should like to ask, and, first, with regard to the lectures that are proposed. I take it that the lectures are paid for—that is to say, you have paid lecturers; they do not give their services gratuitously, and that the students attending pay a fee? I do not see anywhere in the Report that that is stated, and young men might come and ask me, and I should not be able to tell them anything about it. I do not know whether that could in some way be added, or in your reply you could tell me what the fees would be?

Then, with regard to the TRANSACTIONS being issued quarterly; this will be very expensive, because I notice now that your TRANSACTIONS and other printing has cost £228, and unless we get the advertisements, which my friend seems to object to, or rather to members canvassing for advertisements, we shall make a very heavy loss. As the American says—

> "Early to bed and early to rise,
> Is not the least bit of use unless you advertise."

(Laughter.) It is a well-known fact with journals and all papers they do not pay unless they have advertisements, and they are very costly to produce

unless you can introduce advertisements. Personally, I do not see any harm in members, not exactly canvassing for advertisements, but trying to obtain them for the Journal.

As I say, the work that this Council has been doing is extraordinary in the way of investigation, and the list of things that you have either considered or are about to consider almost appals me, because I understand I have been elected on the Council, and if I am to take part in this gigantic work I really tremble to think what the consequence may be. On page 159 you have a list of seven matters which you are going to consider, from reinforced concrete piles down to the effect of oils and fats on concrete. On page 160 you have got the effect upon steel of the presence of sulphur in aggregates, and four others, winding up with the erratic results obtained by the Vicat needle in ascertaining the initial set of cement, and, lower down, methods of treating the surface of concrete and cracks due to expansion and contraction of reinforçed concrete. All that is a terrific programme, and I only hope that we shall be able to get through one-tenth of it.

I was going to suggest another investigation, and that is, when we hear of failures in concrete that a committee should thoroughly investigate the reason of those failures. Fortunately we have not heard of so many lately, but many of them are mostly exaggerated. I do think that something of the kind should be done, that where we do hear of any failure in reinforced concrete we should thoroughly investigate it, and see if it is due to the reinforcement of the concrete or to some other cause. I have great pleasure in supporting the adoption of the Report.

Mr. T. C. DAWSON, Assoc.M.Inst.C.E. :—I have only one suggestion, in also supporting the Report, and that is, in the TRANSACTIONS the advertisements, if obtained, be not embodied in the pages of the ordinary matter, but kept at either end.

Mr. F. E. WENTWORTH-SHEILDS, M.Inst.C.E., V.P.C.I. :—I should just like to say, sir, that I am very pleased to see that the Committee who had in charge the suggestions for widening the scope of the Institution have suggested as the sub-title "An

Institution for Structural Engineers, Architects, etc." I am very delighted to see that "etc."—(laughter)—because I think there was a little tendency at one time for our Improvement Committee to rather rule out anybody except engineers and architects ; and I think it is the strength of this Institute, sir, that we have been able to combine so admirably the brains and the work and the good fellowship of so many different men representing the building trade and profession in all sorts of different ways. We have engineers, we have architects, we have specialists, we have chemists, we have contractors, we have every sort of person who is interested in structural work. This feature of the Institute is in some ways unique, and has been of immense help to us—it has enabled us to get the various subjects which we have investigated looked at from all points of view. I hope it will continue to the end of the chapter.

About advertisements, I sympathise with Mr. Serraillier's idea. It is not very nice to have to advertise, but, on the other hand, we must face the fact that we have got a great deal of expense, and that we have not got enough money coming in for that expense. Well, surely it is better to put advertisements in our Journal rather than raise the subscription and so make it more difficult for those who would like to join the Institute and get its advantages. Probably this thought will reconcile us even to the terrible idea of having this or that brand of cement or of reinforcement writ large at the end of our Journal.

THE CHAIRMAN (Sir HENRY TANNER) :—There are not many points which I have to answer. The principal ones are the observations of Mr. Sachs, in which he used such flattering words in regard to myself. I am not aware that I have done so very much, but of course I have had the interest of the Institute at heart ; I have done what I could for it, but every one of us has done the same and we all work together. However, I am very much obliged to Mr. Sachs.

Then Mr. Serraillier made some observations. We do want the advertisements for the income which we hope that they will bring in, and we shall put them at both ends of the book. The Institute of British Archi-

tects and the Architectural Association both accept advertisements, so that I cannot see any harm in our doing it. The Civil Engineers do not, but that Institution is much better off, which makes all the difference.

In regard to the question about the lectures, we have only had one course of lectures, and we neither paid the lecturer nor did the students pay a fee. I cannot see why they should not, and I cannot see why the lecturer should not have something for his trouble and out-of-pocket expenses. Anybody who wants lectures by way of instruction should pay something for them. That is a matter which the Council will have to consider before they issue the particulars.

Then as to the printing of the quarterly issue, we have had many complaints as to the irregularity of the publishing of the TRANSACTIONS. They got rather out of date and people forgot all about them, and they were not of so much service, so we decided that they should be issued quarterly. We have cut down the size, and also altered the type, producing them on a cheaper scale. They are quite adequate for the purpose, and we also propose still further to reduce the cost by sub-editing some part of what is submitted for appearance there in the future, and we propose to leave out some of the particulars as to Committee meetings, etc., not usually published.

The subject referred to by Mr. Boulnois should be examined into, but it is not so easy to do so, as failures are kept secret as a rule. (Hear, hear.)

As to what Mr. Wentworth-Sheilds said, of course, the "etc." was meant to cover anybody not exactly belonging to the two professions, and the wider we can spread ourselves so much the better it will be for us and the more support we shall get generally.

With those explanations, which I hope are satisfactory as far as they go, I will now put the proposition that the Report be received and adopted.

On a show of hands :—

THE CHAIRMAN (Sir HENRY TANNER) :—That is carried.

I will now read you the Report of the scrutineers on the Annual Election of Members of Council.

[*Copy.*]

May 1, 1912.

DEAR SIR,—

We, the Scrutineers to the Council Election of the Concrete Institute, have found as follows :—

Section I.	*Votes.*
Shore, T. B....	181
Serraillier, Lucien	177
Munro, John...	176
Section II.	
Searles-Wood, H. D.	160
Bamber, H. K. G.	156
Vawdrey, R. W.	136
Boulnois, H. Percy	132
Drew, Alexander	132
Scott, A. Alban H.	132
Garbutt, Matt	123
Harvey, R. Napier	105
Davis, A. C....	92
Fraser, Percival M.	73
Hills, Osborn C.	72
Tingle, H. J.	50
Watson, T. Aubrey	35
Wager, Jasper	32

One hundred and ninety-five voting-papers were received.

There were four spoiled papers.

The votes of two members had to be ignored owing to their subscriptions being in arrear for 1911.

Three papers were rejected owing to the envelopes not being signed.

Yours truly,
(*Signed*) P. W. LESLIE.
A. W. BUNGARD.

The President, Concrete Institute.

THE CHAIRMAN (Sir HENRY TANNER) :—The first twelve-named are elected. We issued with the voting-papers a paper asking the opinions of members

as to the time of the meeting and whether they considered the Hall satisfactory, and the result was 59 voted in favour and 11 against the present Meeting Hall ; in regard to the hour of the meeting, 37 voted for 7.30 p.m. and 30 for 8 p.m. So as regards the Hall, it seems quite satisfactory, but on the other point opinion is nearly equally divided, and the Council will have to take the matter into consideration.

MR. JASPER WAGER, A.R.I.B.A., M.C.I. :—I am asked to move the appointment of Messrs. Monkhouse, Stoneham & Co. as Auditors of the Accounts for this year at a fee of five guineas.

MR. T. C. DAWSON, M.C.I. :—I second that proposal, and I do so with great pleasure.

THE CHAIRMAN (Sir HENRY TANNER) then put the resolution to the meeting and it was unanimously adopted.

THE CHAIRMAN (Sir HENRY TANNER) :—The next business we have is to present our medal to Professor Beresford Pite—(cheers)—which the Council has awarded to him for his paper on "The Æsthetic Treatment of Concrete," and in presenting it I should like to say that it was a most interesting contribution to the literature of the subject treated ; and it gave rise to some discussion, although this was limited in extent. The architects did not turn up, as we had hoped, to take a considerable part in it. We expected that they would, as we had sent a very wide invitation to them ; but I think there were only two or three who came to hear and to discuss this paper.

I am glad that the Professor did not altogether object to what had been done and advocate something entirely new, because I think we should have got into very much trouble, and the results would have been much like they are in some foreign places, where the architecture in reinforced concrete is not very satisfactory, to Englishmen at all events. But he did not do that ; he said we ought to start from the existing styles of architecture, and that seems really to be the most satisfactory way of meeting this difficulty, because it *is* a real difficulty. Nobody has developed anything yet which, when new, is satisfactory. However, there is no doubt that something

will develop shortly, and the Professor has given us a start in that direction. Perhaps the Royal Institute might develop a discussion itself, and so make some greater effort than has been done hitherto. It rather sits upon this sort of thing. I do not think I need waste your time in saying anything more, but I would ask the Professor's acceptance of this small memento of our regard for him and his lecture. (Applause.)

THE CHAIRMAN (Sir HENRY TANNER) then handed Professor Beresford Pite the Bronze Medal of the Society for the best paper read in the 1910-11 session.

PROFESSOR BERESFORD PITE, F.R.I.B.A., M.C.I. :—I beg most sincerely and heartily to say how much I appreciate the honour that the Council of the Institute has conferred upon me in bestowing this medal for the paper. It is due, of course, to the interest of the subject, which dealt with an aspect of work in concrete that has not yet captured the imagination of members of this Institute as I hope it will in the future. One cannot but be sure that if the apparent fog that hangs over progress in the architectural aspects of concrete construction is dispelled by a little clear light there ought to be a considerable acquisition of width and breadth to the operations of this Institute. So long as this subject remains unexplored and unexperimented upon, so long this Institute will be looked upon as merely a body concerned with certain aspects of building, and with those only ; and concrete construction, especially in its more prominent methods now, will be relegated to the larger, coarser, and greater class of building, when it might, if their interest and enthusiasm and hope and light are awakened, be used for more monumental, decorative, and homely, and therefore much wider, purposes.

It seems to me that since it is recognised that there is a field for experiment, for movement, and for intellectual thought, a field which connects a contract in concrete building with an ordinary and regular course of architectural study of æsthetic construction, then there should come the widened scope which your Special Committee so hope for, and which they have in a way suggested, by adding the word "Architects" to the title of the Institute. That widened scope will

come with a very broad, large, and I should like to say popular, appreciation of the artistic possibilities of concrete, because the popular aspect of this subject is, of course, one closely allied to the commercial one. The union of the commercial constructional aspect and the popular artistic aspect ought to make this Institute a very wide and a very important public body.

I should only like, sir, to make one suggestion with regard to this, which I think is a practical suggestion, and not inappropriate, connected with the honour that you have courageously bestowed upon an unworthy person to-day, the suggestion is that this subject should not be dropped, but the attention of architectural students and designers should be drawn to it. The Chairman has indicated that the Institute of British Architects do not pay much attention to it. He is perfectly right. I think if he had said bluntly that they are prejudiced with regard to the whole subject of concrete he would only have spoken what he feels, and what with some delicacy we know he hesitated to express. The best way to disperse that prejudice will be to show what great and good designs can be perhaps imagined, because every castle has to be built in the air before it can be built on the earth by young and enterprising designers, and the setting up by this Institute of an annual competition in designs would, I think, attract at all events a certain number of responses ; but I am sure it would attract a few intellectual and careful thinkers on the subject of æsthetics. Those students who have little else to think about in their youth but the charm of design, will turn with interest to such a competition, if the Medal which you have now created, and which is such an artistic object, is bestowed with such monetary attraction as either a special fund or some contribution from the Institute as it might be able to afford annually for a design would supply, the subject of a design being to deal with the simple architectural aspects, elevation, and details suitable for application to, or execution in, reinforced concrete, with, if necessary, any descriptive theory as to the method of design. I think, without expecting too much in the way of hard labour from the competitor, the Institute will be put into possession annually of a number of interesting

artistic essays, that is to say artistic inventions, or designs, and will attract to itself the attention of students as well as to its meetings, and having the designs, no doubt, sir, they will be as beneficial to the publication of your proceedings as the advertisements with illustrations at the end. (Applause and laughter.)

Personally, I always look upon those advertisements with a great deal of interest when they deal with technical and practical subjects. The illustrations of designs in reinforced concrete would have a most important influence upon the whole subject. Any one who takes up the TRANSACTIONS will say that here is a live and popular aspect of the question, which this Institute is alive to, you will attract to yourselves those of the general public who are very widely interested in the outward aspects of the buildings, and of art critics and others who certainly should be made conscious of the fact that a new and effective building material has come into practical use. The world will move, as it always has moved in these artistic matters, slowly, but with increasing interest, life, and enthusiasm.

Again I venture to thank you very humbly and very earnestly and very cordially for the kindness of your presentation this afternoon. (Applause.)

THE CHAIRMAN (Sir HENRY TANNER):—The next business, gentlemen, is for me to vacate this Chair and to put Mr. Wells into it. In Mr. Wells I am sure you will have a President quite suitable to the Institute, not an amateur—(hear, hear)—one who is thoroughly acquainted with the business or with the profession of a designer in reinforced concrete, not like myself, an amateur, and I am sure he will make you a most excellent President, and I feel great confidence that the Institute will certainly advance under his guidance. (Applause.) I therefore will make way for Mr. Wells and wish him the best possible luck during his two years of office.

MR. E. P. WELLS, J.P., accordingly took the Chair and said: Sir Henry Tanner and gentlemen, I have to thank Sir Henry especially for the very kind words that he has said, and for the manner in which you have received the same. I do not intend now

making any remarks, but to say that during my term of office as President I trust that in all my dealings with every member I shall be thoroughly impartial, and I shall do the best that I can for the interests of the Institute. (Applause.)

Mr. A. Alban H. Scott, M.S.A., M.C.I. :—I have the pleasure of proposing a very hearty vote of thanks to Sir Henry Tanner for taking the President's position for the last two years. I hesitated to accept this duty this evening because I felt it should be in more capable hands ; fortunately, however, Mr. Sachs has already said practically everything which should be said on an occasion of this sort, and I can only heartily endorse his feelings.

It will be most difficult to secure another President to take up such energetic work on behalf of this Institute as Sir Henry Tanner. He has given up an immense amount of time, and the courtesy which he has always shown to every one with whom he has come into contact will also never be exceeded, and further, Sir Henry has always been on the spot when he has been required, and if Mr. Wells is so fortunate as to be able to follow such a splendid precedent it will spell further progress for the Institute. I have the greatest pleasure in proposing a most hearty vote of thanks to Sir Henry Tanner. (Applause.)

Mr. W. G. Kirkaldy, Assoc.M.Inst.C.E., M.C.I. :—I should like to be allowed to say, in seconding Mr. Scott's proposal, that I think the Institute and all the members are very much indebted to the labours of Sir Henry Tanner, who has thrown his whole heart into it during the last two years. As Mr. Sachs has said, he has steered us through rather critical times and worked exceedingly hard. There are not many institutions who are so fortunate as to have presidents who have given so much energy to their work. I am only too glad to know that we shall have his hearty co-operation afterwards, although not in the Chair.

Personally, I should like to record the great pleasure I have had in working with Sir Henry Tanner. I am sure every member on Committee who has come into contact with him has experienced his great courtesy, and also his business ability in pushing things

forward, in getting a lot of work through in a very short time, and yet by his courtesy in hearing any remarks in discussion he has been able to draw out, I think, the points of all parties. It has been a great pleasure to me to come into contact with him, and I just make these remarks in seconding the proposal of thanks. (Applause.)

THE CHAIRMAN (Mr. E. P. WELLS) :—I now put this to the meeting, that a most hearty vote of thanks be accorded to Sir Henry Tanner for occupying the Chair for the last two years as President, which has been so ably proposed by Mr. Scott and seconded by Mr. Kirkaldy. I will put that to the meeting, and I am sure every one will join in it with acclamation. (Applause.)

The resolution was adopted by acclamation.

SIR HENRY TANNER :—Gentlemen, I have had great pleasure in listening to what has been said, and I thank you extremely for the vote of thanks which you have given me for any services which I have rendered during the past two years. Mr. Sachs has already made observations to this effect, and I have answered them, and that takes rather the wind out of my sails at this time ; but I can only say that it has given me very great pleasure to attend these meetings and the meetings of the Council. I have made many friends there, and I hope to continue my attendance. I have continued as President of the Institute for as long as was beneficial to it, and there are many who are more gifted for such a position than myself. I think you have now a President better fitted for the purpose than I have been. We have, however, got the business through, and we have arrived at a point which is certainly not backward from what it was two years ago, and for that I have to thank the members of the Council, our Secretary, and all concerned. I thank you very much, gentlemen, for your vote of thanks. (Applause.)

The meeting then terminated.

The accompanying photographs illustrate (exact size) the bronze medal presented to Professor Beresford Pite. The obverse is the same as the Seal of the

Concrete Institute. Mr. Cecil Thomas (of 1, Great Pulteney Street, Regent Street, London, W.), who designed and engraved the seal, medal dies, and certificates of membership, has supplied the following explanation of the design of the medal :—

"The motive of the obverse is : Great strength combined with beauty ; typified in the strong and firm

THE MEDAL OF THE CONCRETE INSTITUTE.

yet beautiful female figure, who holds an important implement used in concrete building. The Lions of Alfred Stevens ornamenting a simple throne and the ornamental border surrounding the whole indicate the artistic nature and strength of concrete construction.

"Reverse : Laurel and Oak for success and strength."

THE SECOND ANNUAL DINNER

Thursday, May 9, 1912

THE SECOND ANNUAL DINNER of the CONCRETE INSTITUTE was held on Thursday evening, May 9, 1912, in the Empire Hall, at the Trocadero Restaurant, Piccadilly Circus, London, W.

Mr. E. P. WELLS, J.P., President of the Institute, was in the Chair, and there were also present :—

As Visitors of the Institute.

Mr. H. Percy Boulnois, M.Inst.C.E., V.P.C.I., Chairman of the Council of the Royal Sanitary Institute.
Mr. R. Elliott-Cooper, M.Inst.C.E., President-Elect of the Institution of Civil Engineers.
Lieut.-Colonel G. E. Holman (of Holman & Goodshaw, architects).
Mr. John Murray, F.R.I.B.A., Crown Surveyor.
Mr. W. E. Riley, R.B.A., F.R.I.B.A., M.Inst.C.E., Superintending Architect of Metropolitan Buildings and Architect of the London County Council.
Mr. E. A. Stickland, President of the Institution of Municipal Engineers, Borough Surveyor, Windsor.

As Members.

Mr. H. H. D. Anderson, *Member of Council*
Mr. H. K. G. Bamber, F.C.S., *Member of Council*
Mr. Maurice Béhar, C.E. (École des Ponts et Chaussées)
Mr. F. Bradford

Mr. C. St. Leger Brockman
Mr. D. B. Butler, Assoc. M.Inst.C.E., F.C.S., *Member of Council*
Mr. Walter Butler, M.Inst. C.E.
Mr. F. Dare Clapham, F.R.I.B.A.
Mr. T. M. Deacon, F.S.I.
Mr. C. de la Salle
Mr. William Dunn, F.R.I.B.A., *Past Vice-President*
Mr. E. Fiander Etchells, F. Phys. Soc., M.Math.A., A.M.I.Mech.E., *Member of Council*
Mr. Albert A. Fillary, District Surveyor for Streatham West
Mr. Percival M. Fraser, A.R.I.B.A.
Mr. James Gardiner
Mr. George H. Gascoigne
Mr. George W. Gray, P.A.S.I.
Mr. F. W. Hamilton, A.R.I.B.A., District Surveyor for Paddington
Mr. Charles D. Hunter
Mr. W. P. Inchley
Mr. Charles J. Jackaman, M.Inst.C.E.
Mr. William G. Kirkaldy, Assoc.M.Inst.C.E., *Member of Council*
Mr. P. W. Leslie
Mr. James A. Malcolm
Mr. John Munro, *Member of Council*
Mr. Stanley V. Nicholson
Mr. W. G. Perkins, District Surveyor for Holborn, *Member of Council*
Mr. James Petrie
Mr. Joseph Randall, Assoc.Inst.C.E.
Mr. George S. Roberts
Mr. Reginald Ryves, Assoc.M.Inst.C.E.
Mr. Percy W. Sankey, Assoc.M.Inst.C.E.
Mr. A. Alban H. Scott, M.S.A., *Member of Council*
Mr. L. Serraillier, *Member of Council*
Mr. C. W. Sharrock
Mr. Herbert Shepherd, A.R.I.B.A.
Mr. T. B. Shore, *Member of Council*
Mr. Alfred Stevens
Mr. J. Osborne Smith, F.R.I.B.A., F.R.San.I.
Mr. Samuel F. Smith
Mr. Samuel A. Stanger, F.S.I.
Sir Henry Tanner, C.B., I.S.O., F.R.I.B.A., F.S.I., etc., Principal Architect H.M. Office of Works, *Past President*
Mr. Henry Tanner, F.R.I.B.A., *Member of Council*
Mr. John M. Theobald, F.S.I.
Mr. Thomas P. Tinslay
Mr. C. G. Napier Trollope, M.A., F.S.I.
Mr. F. E. Wentworth-Sheilds M.Inst.C.E., Dock Engineer L. & S. W. Rly., *Vice-President.*
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Mr. Maurice F. S. Wilson, M.Inst.C.E.
Mr. W. H. Winder, M.S.A.

Also Mr. H. Kempton Dyson (Secretary) and a Representative of the Central News, Ltd.

After the submission of the loyal toasts by THE CHAIRMAN (Mr. E. P. Wells),

Mr. W. E. RILEY (Superintending Architect of Metropolitan Buildings and Architect of the L.C.C.) rose to propose "The Concrete Institute." He said:—Mr. Chairman and gentlemen, A compliment has been paid to me in asking me to say a few words on the Concrete Institute—I think I may say the toast of the evening, without any derogation of those loyal toasts which have been received so enthusiastically by you all. It seems to me only the other day that there was no such thing as the Concrete Institute. Indeed, I remember the beginning of this Society when

a few well-known experts laid their heads together and began to think how coming problems could be dealt with, and I see a little the effect of it now before me in a healthy and vigorous Society (Hear, hear.) I believe you have between nine hundred and a thousand members, and I congratulate you upon the great success you have achieved already. We all well know, all of us who have been pioneers—as I have been myself on many occasions in life—that pioneer work is generally a very thankless task. I do say that those who inaugurated this Society had very far-reaching thought, because, whether we like it or not, reinforced concrete and concrete generally have come to stay. (Hear, hear.) Those of you who have been through an architectural training understand the problems I have in mind. But I am a man who must in the course of nature be nearing the close of his official career. The man who is going to make a mark in life is the man who is going to show adaptability and commercial interest. I say this Society is the absolute embodiment of that idea. I have heard men say, and I think they are misguided, that they are sorry some one discovered that putting steel down a piece of concrete made it stronger. We know the commercial world is not sorry for that ; the commercial world is going to be glad. I have always felt it my duty, so far as I had any idea of the cut-and-dried administration of rigid laws, that the proper thing for any one to do was to try and make those rigid laws elastic by administering them with benevolence. I will remind you that the aims of concrete experts have been greatly aided by three or four changes in the law. They were based on rigid principles, but you found you could apply them with more elasticity than you thought, and that they encouraged the application of new materials. I heartily congratulate you, Sir, and the Council in taking up reinforced concrete which can be applied properly, economically, and commercially in buildings in large towns. That is, I think, a subject you ought to be very proud of. (Hear, hear.) I was recently at Rome, and I was glad to see that the Congress of Architects there gave a good deal of time and consideration to the question of reinforced

concrete. I grant you, at the same time, that the conclusion of the whole matter was—no one knew how to treat it. Some thought it was papery, thin, and expressionless, and so on. But you know the right thing will evolve. I think the aims of this Society will result in obtaining proper and artistic expression by those who are trying to interpret building materials. I feel somewhat diffident speaking to an Institution like this about regulations, but the onerous duty has been thrown upon me in trying to do something in putting the Regulations on a proper footing. Nothing will be ideal, but you must try and make them as practicable as you can. Any amount of personal effort has been exercised to try and make them go. (Hear, hear.) It is a very cheap thing to tell me that I have been saying two and two make four. I know I have said that before on several occasions, but I have always had to make two and two four, although some people try to make them five. (Laughter.) There is something about the Regulations, and this is the only opportunity I have had of saying it before. I am deeply grateful—and I believe I am expressing the views of those in authority at the London County Council—we are deeply grateful for the enormous assistance we have had from this Institute in endeavouring to pioneer and do something in London. Of course, I am not going to say any more about them, because they are *sub judice*, but I hope they will soon appear and that we shall know where we are. We went through every possible source of information we could think of, and tried to get the practice of other countries and to codify them for the benefit of all. There is one thing I can most heartily congratulate you upon, and I do it with a most profound feeling, and that is of having an eighteen-carat man as the outgoing President, Sir Henry Tanner. I have known him for many years, both officially and in private life. You know your present President is an old friend of mine, and an old opponent too. (Laughter.) He was an old colleague of mine at the County Council, and we all respected and appreciated him there, and I am sure you have done the right thing in making Mr. Wells President of your Institute. (Hear, hear.) I am sure he will not mind

my reminding him that we had many strenuous fights over the legislation of 1909. I faced nineteen opponents there, and he was the nineteenth of the opposition, and you know what that was. I am sure you will not be surprised to hear that the Rules that we then drew up were not too stringent—in fact, not stringent enough. You know when one speaks about this kind of thing one remembers—and I do it with gratitude—although we were opponents over the negotiations, I do not think that we thought the worse of each other. I speak for myself, and, of course, never for a moment was there a bitter thought. They frequently told me they were trying to gain veracity from an architect, and I tried to gain veracity from nineteen men. (Laughter.) I cannot help saying this about the long-looked for Regulations—they do aim at trying to help you thoroughly and to do what you want—namely, to give a fillip and to give the benefits of your enormous thought, experience, and services to those who are willing and anxious to give commercial development to the great work which you have been endeavouring to bring to fruition. I thank you heartily for giving me the opportunity of thanking this Institute for the great help you have given me personally in endeavouring to make those Regulations such that they will be workable and practicable. I give you "The Institute," root and branch; may it prosper, and I couple with this toast the name of your able President. (Cheers.)

Mr. WELLS, upon rising to respond, was received with cheers. He said :—Mr. Riley and Gentlemen, in responding to the toast of the health of the Concrete Institute, allow me to thank you for the kind words you have said on behalf of that Institute, and also for those you have said about myself. Before we go into other matters let me thank you, sir, for, as I consider, the extremely impartial attitude that you have adopted all through the negotiations that have passed between the Concrete Institute and yourself in regard to the new regulations about to be laid down for reinforced concrete, and also at the same time for the fact that everything that has been done has been carried out in the best of temper. I am happy to say that in

every case where suggestions have been made by the Institute they have been listened to, and where they have been found to be perfectly just they have been accepted without a murmur. I have also to thank you for the able lieutenant you have chosen to carry on the negotiations with this Institute, and more especially the one with whom we have been directly connected. I trust, sir, that in the negotiations you are about to carry on with the Local Government Board they will be carried on in the same spirit as existed between the Concrete Institute and yourself. One thought struck me in connection with the disaster to the *Titanic*, and that was that if London was in the grip of a very severe frost, and the greater part of the mains frozen, what would happen? Looking back on the Great Fire of London, if such a thing happened now and half the mains were frozen, the conflagration would result in one of the most appalling disasters that has ever taken place. The regulations to be put forward by the L.C.C. have for their primary object the protection of life and property. Personally, I shall uphold those regulations throughout, because I feel convinced that though they may at the time appear a little hard, still they are for the benefit of London as a whole. If we put up buildings that are as near as possible absolutely fireproof, though it will be more costly, still it will be cheapest in the long run. Therefore I am of opinion from what I have seen and what I have had to do with the 1909 Act (steel frame section) that certain portions ought to be made more strenuous than in the present Act. I hope that if anything is done in the future that certain clauses will be added so as to place everything in such a condition that no one will be able to alter or evade the clauses in any shape or form whatever, and whenever we have a building erected in accordance with the Regulations we may be perfectly certain that if a conflagration takes place that very little damage will be done, if any, outside the building where the fire originated. There are one or two here who think that the Regulations as regards reinforced concrete are a little hard, but I think that when the Act is thoroughly gone into and applied, that it will be found that they will be beneficial all round. A most

interesting paper was read in the last session by Professor Beresford Pite, for which the Council felt justified in awarding him the medal. We all hoped he would have been here to-night, but unfortunately he has to deliver a lecture at the London County Council School of Building upon Architecture. Every one, I am sure, would have been pleased to see him here to-night. The discussion on that paper was a most interesting one, and will, I think, eventually lead to some definite kind of treatment in concrete and reinforced concrete as a whole. I think a special line may be adopted in regard to concrete and its treatment, and the Council are going to consider the question of offering a yearly prize for the best form and treatment in concrete design, and I hope we shall have something interesting laid before us. This year the Council are going to institute educational lectures for the younger members, and I trust they will be attended not only by the younger people, but also by some of the older ones to give help to the lecturer. I am happy to say that the total number of members is nine hundred and twenty, and hope before the year is out that the number will be a thousand, and that in the next two years or so we may see the number go up to two thousand or over. (Hear, hear.) With the small number of members we have at present, with an annual subscription of a guinea, it takes us all our time to make both ends meet. It leaves nothing in hand to make experiments with, and we have to depend entirely upon individual efforts, and we know perfectly well that when it is put upon two or three it becomes a great drain upon their resources. So I trust the time is not far distant when we shall find that our numbers are increasing rapidly, and that with a membership of two thousand we shall be able to spend money for the good of all. In conclusion, I hope that this Institute may be like the material from which it takes its name, and that it will increase in strength, numerically and financially, and I trust before long that I shall be in a position to say that the Concrete Institute has attained a membership it never dreamed of years ago, and that many we have here to-night as visitors will join the Institute and become working members. Gentlemen, allow me to thank you on behalf of the Concrete Institute for the

manner in which you have responded to the toast, and to Mr. Riley for the kind words he has said. (Cheers.)

Mr. F. E. WENTWORTH-SHEILDS, M.Inst.C.E., Vice-President of the Concrete Institute, in rising to propose the toast of "The Visitors," said :—It is with pleasure that I rise at your request to propose the health of the guests. It is a great joy to us, the members of this Society, to see them here, and I hope the pleasure is mutual. Certainly the compliment—if compliment it is—is mutual. We have the honour to-night to offer them hospitality, and they in return are giving us a great deal by their presence here. They are giving us their sympathy and their help and their support. They are giving us the best gift that can come from man to man—the gift of friendship. A young society like this naturally looks with pleasure at its achievements. Young people, of course, are sometimes mistaken about their own achievements, and inclined to set higher value upon them than they should. This reminds one of Mr. George Russell's story of a children's party he attended, where there were two dear little girls boasting of the things they possessed and of the grand things they had done. One little girl said, "My hen laid an egg this morning," and the other little girl, the daughter of a bishop, threw her little chin into the air and said, "Oh, that is nothing ; my father laid a foundation-stone." (Laughter.) Being a young Society, we perhaps take that view of things. We think we have laid a foundation-stone "well and truly," and we believe we are building a good superstructure upon that stone. We are able to point with pardonable pride to our membership, which is now nearly a thousand strong. We can say that the work which we have done has been useful not only to structural engineers, but to builders generally. We have suggested rules by which the calculations and drawings for reinforced concrete designs will in future be simplified. We have been able to show how to build structures which will not only be strong, but which will last for our generation and for many generations to come. We can also say with satisfaction that Parliament has entrusted us with the work of offering our criticisms and suggestions

about the Rules which the London County Council have drawn up for the guidance of builders in reinforced concrete. After the kind things that Mr. Riley (who is responsible for those Rules) has said to-night, you will gather that he appreciates what we have done in this direction. I think, sir, that not only may we take pride in the little work we have been able to do, but we can also feel gratified that our guests have, by their presence and acceptance of our hospitality, expressed their sense of the useful work done not only to the profession, but to the world at large. You requested, sir, that speeches should be short, so mine will be. But I should just like to echo the hope you expressed, that many of those who are guests here to-night will be hosts next year, that they will join our Society and help in the work we are doing with their experience and their advice. In any case, we hope this occasion will be by no means the last at which we shall have the pleasure of welcoming them. There are so many distinguished guests that it would take too long to mention them by name, but, as an engineer, I should like to say how pleased we are to see the President-elect of the Institution of Civil Engineers —(Hear, hear)—and I should like to couple with this toast the name of Lieut.-Colonel G. E. Holman. I give you the toast of "Our Guests," and call upon you to drink it with great heartiness. (Hear, hear.)

LIEUT.-COLONEL G. E. HOLMAN, in responding, said :—Mr. President and Members of the Concrete Institute, I am sorry for you that I am in this position to-night, but it is not my fault. I asked my friend, Mr. Dyson, why, in the face of the galaxy of scientific knowledge here to-night as visitors, I should be asked to reply for the guests, and the reply was that some of the gentlemen had spoken before, or that others were going to speak to-night, and therefore it devolved upon me as a guest to respond for the visitors. Hence I am standing up answering for the visitors. Mr. Riley told us one of the best stories to-night—far better than the gentleman on the platform. He told us how Mr. Wells and a few others put their heads together and formed the Concrete Institute. (Laughter.) I always knew my friend was a hard-headed man. I have known him for many years, and the longer I

have known him the more I have learned to respect, admire, and love him. The most scientific of men, he is ever anxious to do things on the right lines. He is now clamouring that the Regulations should be made more stringent. I did not hear Sir Alfred Gelder say anything to that, and I did not hear any architects clamouring for the same thing. Mr. Wells made me anxious, because architects must consult engineers from the Concrete Institute. But I am sure of this, that anybody who knows our friend Mr. Riley will endorse all he has said about the administration of the Acts, and that they are administered with benevolence and not with that rigid cast-iron rule, as outside the London area. We, as architects, have no complaints to make of the administration of the law. May I say on behalf of the visitors that I echo all their sentiments when I say that we have enjoyed ourselves very much indeed, and we are glad to have been asked to come. I hope those of us who are not members will be asked again next year. (Hear, hear.)

Mr. HENRY TANNER, F.R.I.B.A., proposed the toast of "The President, Mr. E. P. Wells."

The toast was given with musical honours, and Mr. WELLS briefly replied.

A musical entertainment supplemented the speeches. It was given by Mr. Frederick Upton, assisted by Miss Doris Clayton and Mr. Edgar Coyle.

The proceedings then terminated.

THE CONCRETE INSTITUTE

AN INSTITUTION FOR STRUCTURAL ENGINEERS, ARCHITECTS, ETC.

CALCULATIONS IN THE DESIGN OF A THRUST BUTTRESS MASONRY DAM.

By REGINALD RYVES, M.Cons.E., Assoc.M.Inst.C.E., M.C.I.

In a paper read before the Concrete Institute on March 14, 1912, there was included a brief description of the writer's type design for a dam of arches supported by buttresses in direct thrust. While there is no theoretical objection to the substitution of reinforced concrete spans for the arches, the fact that the whole of the structure is subjected to compression stresses points to the probability that for large works the most suitable material will usually be plain masonry, and the most suitable form for the waterproof wall a segmental arch. The following calculations for a dam of plain masonry would apply in the case of a similar dam made of reinforced concrete, regarded as a material, and in such a case the actual stresses allowed at different depths in the arched wall and in different layers of the buttresses might be varied according to the proportion of reinforcement and its distribution as designed for the development of high compressive strength. A design intended to economise in the quantity of aggregate used in the concrete might, in the case of a highly stressed reinforced concrete dam, have to include the provision of inverts, parallel to the

water face, connecting the bases of the buttresses and distributing the load upon the rock. Footing out or battering out the foundations might in such a case involve either the carrying of the bottom ends of the buttresses to considerable depths in the rock, involving the provision of a good deal of masonry for this purpose alone, or such an angular divergence from the line of direct thrust as would amount to a secession from the principle on which the design is based, and might involve the introduction of tensile stresses such as those in the bases of reinforced concrete columns.

The writer does not think that such designs are likely to offer economical advantages, though, since it may be realised that there would in such cases be advantage in departing as little as possible from the thrust buttress type, it is as well to recognise designs of this character as structurally possible.

The Advantages of Plain Masonry.

As regards expansion and contraction the form of the thrust buttress dam is probably as favourable to plain masonry as to reinforced concrete, and, apart from its permanency and resistance to weathering, plain masonry offers one prime advantage and two secondary ones, of great significance in the present connection. The prime advantage is that it is nearly always and nearly everywhere the cheapest material to use per unit of thrust intensity. The two secondary advantages are, first, that near the bottom of the dam and in the ground it is easily put in place, may be safely left at different stages of construction, and easily repaired if damaged ; and, secondly, that near the top of the dam, where, for practical reasons, the dimensions of the parts must exceed those found by the calculations for strength, its cheapness per unit volume is strongly in its favour.

The following calculations, then, apply to plain masonry, and, if they are to apply to reinforced concrete, it must be clearly understood that it is reinforced concrete regarded as a material and designed to withstand thrust, and that the reinforcement must not pass from one buttress layer to another, nor be used to tie different parts of the arches together, or arches to

buttresses, in such a way that under changes of water level or changes of temperature the dam will gradually develop stresses other than those which occur with plain masonry. It will probably be found that the most economical application of steel reinforcement to the masonry of a thrust buttress dam will, as regards the arches, be radial, and as regards the buttress layers, horizontal and transverse, some rods at right angles to these—that is, parallel to the water face and inclined at 45 degrees—being added in the part of the layer which is not covered by the next above it. As regards plain masonry, if mass concrete or mass rubble be used there must be surfaces of separation between the buttresses, and similarly, if the buttresses are built of blocks or of coursed rubble, there must be no breaking joint where the layers meet, and one face of every block should be parallel to the water face of the dam.

THE CALCULATIONS.

There are only two sets of calculations, one for the thickness of the arches, depending on the stress allowed, the radius given, and the depth ; and another set for the calculation of the width of the buttress at any point, the method being the same for the upper end, for the lower end, and for any cross-section of the buttress layer.

The Arch Thicknesses.

For preliminary calculations a rough approximation to the thickness of an arch ring subjected to water pressure is obtained from the formulas :—

$$\text{arch thickness} = \frac{\text{arch thrust}}{\text{arch pressure allowed}},$$

$$\text{arch thrust} = \text{water pressure} \times \text{arch radius},$$

and—

$$\left.\begin{array}{c}\text{water pressure in tons}\\ \text{per square foot}\end{array}\right\} = \frac{\text{depth below water surface in feet}}{36}$$

For depths down to 80 or 100 feet a fair approximation to the maximum pressure in the arch is given by—

$$\text{arch pressure} = pr \times \frac{11}{10}$$

where—

$$p = \text{water pressure}$$

and—

$$r = \text{outer radius.}$$

For final calculation we may use—

$$\text{thickness of the arch ring} = \text{outer radius} \times \left\{1 - \sqrt{1 - \frac{2p}{\sigma}}\right\}$$

Where σ is the maximum allowable stress and p is the water pressure.

This formula may be used if we keep the same outer radius and thicken up on the other face.

If we work from the mean radius we may use the formula—

$$\text{thickness of the arch ring} = \frac{\rho\sigma}{p}\left\{1 - \sqrt{1 - \frac{2p}{\sigma}}\right\}^2$$

where ρ is the mean radius.

Captain Garrett has a table (Table I.) for the expression—

$$\frac{\sigma}{p}\left\{1 - \sqrt{1 - \frac{2p}{\sigma}}\right\}^2$$

which reduces the calculation to the working out of a series of the equation—

$$\text{thickness} = k\rho$$

The radius will depend upon the span and upon what angle the chord subtends at the centre of the striking circle. Captain Garrett has made calculations which show that the arch ring which is most economical of material is one which subtends an angle of 133° 34′ at the centre of the circle, assuming the thickness of the arch to be zero at the top. With an arch ring several feet thick at the top a smaller angle becomes more economical, 120° giving, usually, nearly the most economical arch.

The writer has adopted, for his type designs of thrust buttress dams, a minimum buttress thickness of 6 ft. which, with spans of 60 ft. centre to centre, gives

TABLE I.—VALUES OF "k" FROM CAPTAIN GARRETT'S "THEORY OF ARCHED DAMS."

Depth.	Maximum Stress in Arch Ring σ.			
d.	9 Tons per Square Foot.	12 Tons per Square Foot.	15 Tons per Square Foot.	20 Tons per Square Foot.
20	·0660	—	—	—
25	·0840	—	—	—
30	·1026	·0748	·0590	—
35	·1219	·0886	·0696	—
40	·1420	·1026	·0804	—
45	·1629	·1170	·0914	—
50	·1846	·1319	·1026	·0750
55	·2073	·1473	·1141	·0831
60	·2311	·1629	·1259	·0914
65	·2560	·1791	·1380	·0998
70	·2820	·1959	·1503	·1084
75	·3094	·2133	·1629	·1171
80	·3385	·2312	·1758	·1259
85	·3692	·2497	·1891	·1349
90	·4017	·2691	·2027	·1440
95	·4363	·2889	·2167	·1533
100	·4733	·3096	·2311	·1628
105	·5133	·3312	·2459	·1725
110	·5567	·3536	·2611	·1824
115	—	·3770	·2767	·1925
120	—	·4017	·2929	·2027
125	—	—	·3097	·2131
130	—	·4547	·3271	·2237
135	—	—	·3448	·2346
140	—	·5134	·3629	·2459
145	—	—	·3818	·2575
150	—	·5789	·4017	·2696

a clear span of 54 ft. subtending an angle of 120° at the centre with a radius of 30 ft. The outer radius of 35 ft. has been taken for all the arch rings.

As the clear span decreases with the depth, the angle subtended decreases, and with some materials it would be better to begin with a larger angle at the top.

In the design shown in Figs. 1 and 2, the arch stress is 15 tons per square foot, this being, in each part of the arched wall, the maximum stress as calculated by the formula given above.

Having decided upon the maximum stress and the radius, the necessary thicknesses of arch rings for different depths can be calculated, a series with 5-ft. intervals being usually sufficient. A study of the table so drawn up may suggest what will be convenient increments in thickness. In Fig. 1 the increment is one foot. The table being retained as a check, the next step is to calculate the maximum depth for each of these thicknesses, as follows:—

The formula for the arch thickness at any depth, H, below the water surface is—

$$t = R\left\{1 - \sqrt{1 - \frac{2HW}{\sigma}}\right\}.$$

Where—

$$R = \text{outer radius}$$

$$W = \text{weight of 1 cubic foot of water.}$$

In this case—

$$= \frac{1}{36}\text{ ton,}$$

and—

$$\sigma = \text{maximum allowable stress.}$$

In this case—

$$= 15 \text{ tons per square foot.}$$

Therefore—

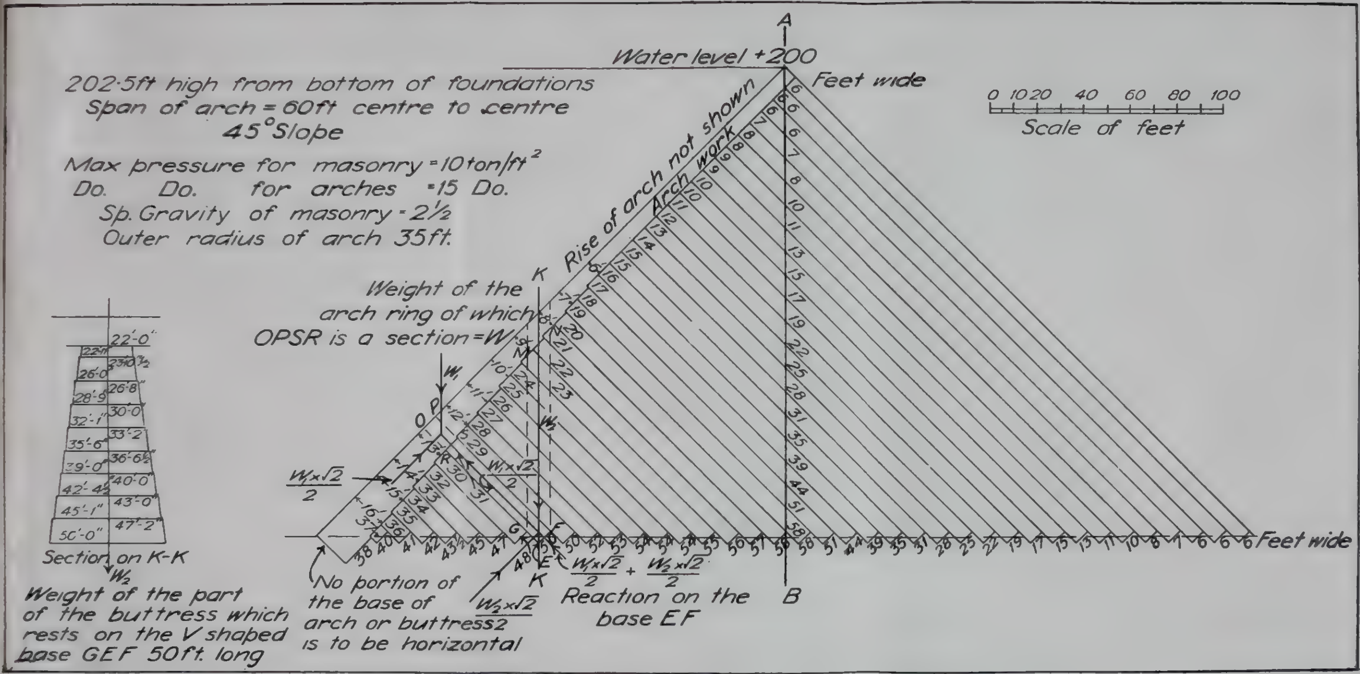
$$t = R\left\{1 - \sqrt{1 - \frac{2 \times 1}{36 \times 15} \times H}\right\}.$$

With an outer arch radius of 35 ft. we get—

$$\frac{t}{35} = 1 - \sqrt{1 - \frac{H}{270}}$$

or—

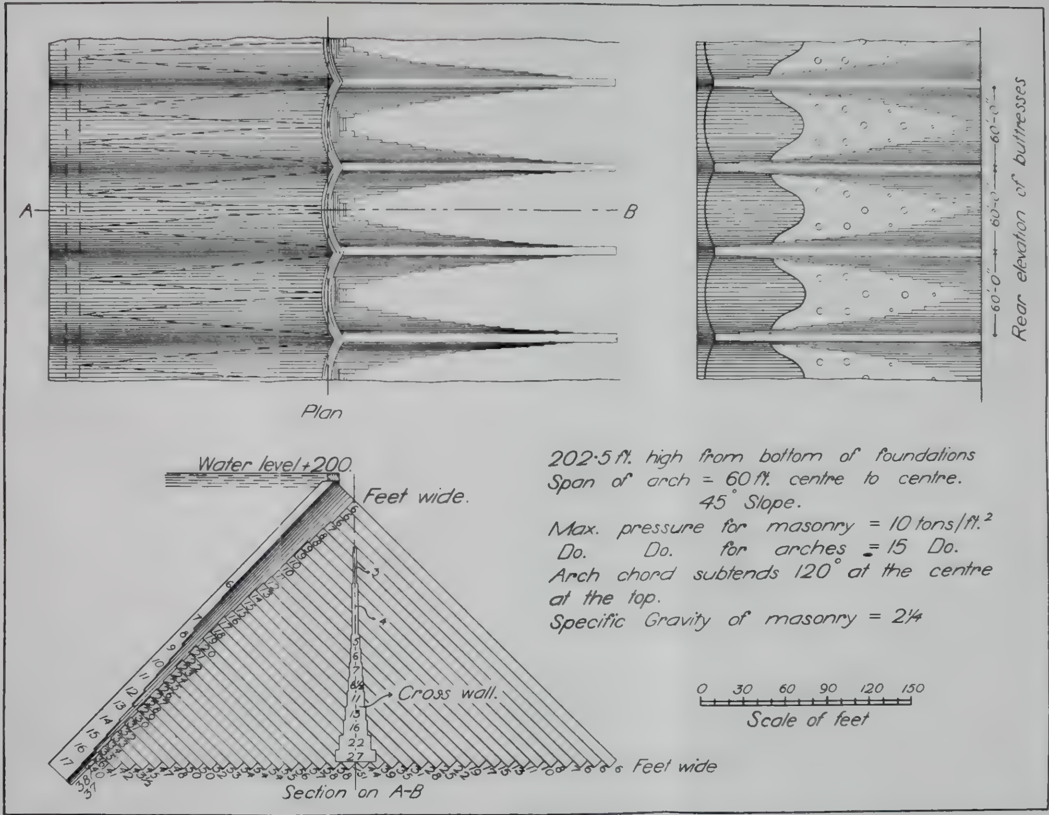
$$1 - \frac{t}{35} = \sqrt{1 - \frac{H}{270}}$$



202·5ft high from bottom of foundations
Span of arch = 60ft centre to centre
45° Slope
Max pressure for masonry = 10 ton/ft²
Do. Do. for arches = 15 Do.
Sp. Gravity of masonry = 2½
Outer radius of arch 35ft.
Water level +200
Feet wide
Scale of feet
Rise of arch not shown
Arch work
Weight of the arch ring of which OPSR is a section = W₁
W₁×√2 / 2
No portion of the base of arch or buttress is to be horizontal
W₂×√2 / 2
W₁×√2 / 2 + W₂×√2 / 2
Reaction on the base EF
Feet wide
Section on K-K
Weight of the part of the buttress which rests on the V shaped base GEF 50ft. long

Fig. 5.

Fig. 1.



A
B
Plan
Rear elevation of buttresses
60'-0"
60'-0"
60'-0"
Water level +200.
Feet wide.
Cross wall.
Feet wide
Section on A-B
202·5 ft. high from bottom of foundations
Span of arch = 60 ft. centre to centre.
45° Slope.
Max. pressure for masonry = 10 tons/ft.²
Do. Do. for arches = 15 Do.
Arch chord subtends 120° at the centre at the top.
Specific Gravity of masonry = 2¼
0 30 60 90 120 150
Scale of feet

FIG. 2.

squaring—

$$1 - \frac{H}{270} = 1 - \frac{2t}{35} + \left(\frac{t}{35}\right)^2$$

whence—

$$\frac{H}{270} = \frac{2t}{35} + \left(\frac{t}{35}\right)^2$$

or—

$$H = \frac{540t}{35} + \frac{270t^2}{1225}$$

$$= 15{\cdot}43t - 0{\cdot}22t^2.$$

This gives the limiting depth, H, for any given thickness of arch, *t*, both in feet, as follows :—

t.	H.
6	84·66
7	97·13
8	109·80
9	121·05
10	132·30
11	143·11
12	153·48
13	163·41
14	172·90
15	181·95
16	190·56
17	198·74

These figures are altered, each to the nearest whole number, or the next higher whole number, which gives the length, measured upwards along the water face, of each thickness of arch. The thicknesses of the buttress layers may be made to suit these lengths, so that exactly one, or some whole number of buttresses, may abut the springing of each arch ring ; but it may be found that this is a needless refinement, and that the thickness of every layer or slab of the buttress may be the same. In Fig. 1 the thickness is $5\sqrt{2}$ ft., which allows of each arch ring, a foot thicker than

the one above it, being abutted by two slabs ; and is a convenient dimension for calculation.

For some depth from the top of the dam the thickness of the arch ring will be greater than that given by calculation, because there will be some minimum thickness depending upon the nature of the masonry. In Fig. 1 this minimum thickness is 6 ft. Towards the bottom of the dam the buttresses are closer together, the clear span at the bottom of a 200-ft. dam being only

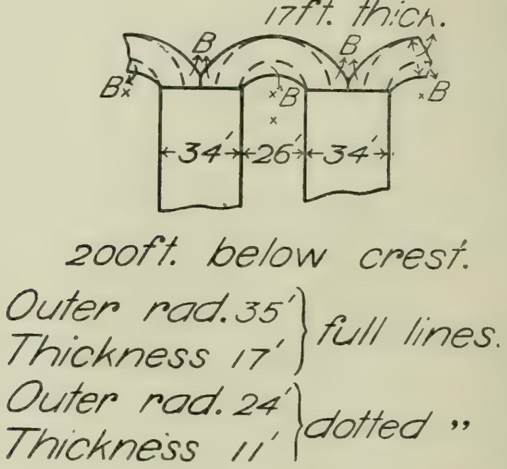


FIG. 3.

26 ft., the pressure in the masonry of the buttresses being 10 tons per square foot. If we regard the clear span as *the* span, and contemplate the providing of a water face to the buttress, the economical arch will have a much smaller radius, and at first sight it might seem worth while making the arches near the bottom with smaller and smaller radiuses in order to economise material ; that represented by the areas marked "B" in Fig. 3. But it is better not to do this. The same outer radius should be kept all the way down, the necessary thickness being given to each arch ring. The arrangement as shown in the full lines in Fig. 3 (at a depth of 200 ft. for 60-ft. spans, centres)

provides for the maintenance of a water apron which is in direct arch thrust across the buttress fronts as well as over the spans ; it allows of the buttresses being built simply to play the part of buttresses in direct thrust, and distinct from that thickness of material which has to be made waterproof ; it permits of the higher stress in the arch rings changing smoothly into the lower stress of the buttresses ; and it maintains the directions of the arch thrusts where each pair of arches meet, so that at the water face they all meet in one straight line and the thrusts near the surface are nearly parallel to one another. A change of radius involves a change in the direction of the arch thrusts at their springings, it exposes a part of the

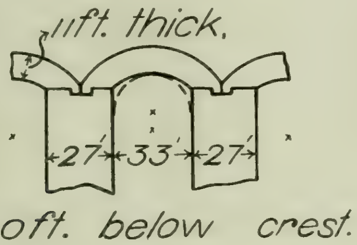


Fig. 4.

buttress as a water face, and it introduces there such stresses as cannot be allowed unless this part of the dam is actually embedded in rock or in very firm gravel under a permanent water or silt load. Even in such a case economy can better be secured by a judicious use of poor material than by a change in shape. If, however, there is any doubt as to the strength of the material towards the base of the dam, a smaller radius may be adopted for the intrados of the arch, as shown in Fig. 4, the dotted line. It may then be assumed that although the maximum stress will not be much reduced near the water face, there will be a reserve of less severely stressed material behind it.

For low dams a considerable part of the arch work will be of the minimum thickness and in excess of the calculated thicknesses. For instance, if with rubble

masonry we adopt a minimum thickness of 6 ft. and a maximum stress of 10 tons per square foot, we shall have a thickness of 6 ft. down to a depth of about 85 ft., instead of a thickness gradually increasing from, say, 2 ft. to 6 ft. In such a case there is, for dams not more than 100 ft. or so in height, little or no advantage in adopting shorter spans, though for materials such as brick, allowing of a small minimum thickness, it is an economy to have small spans and a small radius.

The inclination, usually 45°, given to the arches results in a crest of varying height. The way in which the crest will be finished off will depend upon the nature of the materials, upon the amount of "free-board" above maximum water level, and upon the degree of strength demanded of the crest. The arched form is a good one for withstanding the assaults of floating timber or ice, and, where the minimum thickness is considerable, it will probably be ordinary practice to stop the building of each course of the arch at crest level, after the crown of the course below these has reached crest level; as though the dam had been completed with the tops of the buttresses at crest level, and the part above this planed off. When the "free-board" allowed is considerable, and the spans are short, a wall, footed upon the arches, may be built from crest to crest, buttressed if necessary. If a roadway of considerable weight be provided, its effect upon the calculations must of course be taken into account, but in the case of a high dam this will be quite small.

Provision for Elastic Movements.

The form of the dam allows of a considerable amount of elastic movement, but in the case of materials which are likely to settle during or after construction, or with materials having a low modulus of elasticity, it may be desirable to allow for movement by making the arch rings with surfaces of separation, conveniently made to coincide with a change in thickness, and, anyhow, coinciding with the surface of separation between two buttress slabs. Then, if a slab moves upon the one below it, it will carry its arch and ring with it without rupture.

There are several ways of making the joint water-tight, two of which may be mentioned. If it be desired to maintain a flush water face, one ring of brickwork or squared stones set in bitumen and centred on the joint may be let in. If the water face is to be stepped (which, as suggested by Mr. E. P. Wells, may be an advantage in construction as a means of holding up the staging) the underhang may be carried up as a lip, the groove behind which may be filled with some caulking material, held down by a ring of loose bricks, or in some similar fashion—on the stuffing-box principle.

THE DESIGN OF THE BUTTRESS.

Each pair of arch springings, or common springings, will be on the face of a buttress, and, since the water face is inclined at 45°, the layers of the buttress will also be inclined at 45°—or, generally, the complement of the water face angle—in order that the resultant of the pair of thrusts from adjacent arch rings may be transmitted directly along the corresponding buttress slab to the rock. Since, however, each layer or slab is held down by the layer above it, and by its own weight, and is steadied transversely by the friction of roughish surfaces, its cross-section need not be calculated as though it were a free strut, but only for direct thrust. The topmost slab is free, but the load on it is very small.

THE STRESS UPON ANY CROSS-SECTION.

The way in which the stress upon any layer is calculated is shown in Fig. 1, in which O P R S represents two half arch rings, and the load upon R S is the resolved part of the weight of these two half arch rings, added to half the water load upon two arch rings.

Taking the case of Fig. 1, the buttresses being 60 ft. apart, centre to centre, the specific gravity of the masonry $2\frac{1}{4}$, or $\frac{1}{16}$ of a ton per cubic foot, and the layers $5\sqrt{2}$ feet thick (5 ft. vertically, edge to edge), let us first calculate the thickness of the buttress slab at the top end, R S. For the purpose of calculation the arch ring corresponding to this slab, and

resting against the front edge, may be taken as 71 ft. long, and it is, at the depth shown, 13 ft. thick, which gives us :—

Weight of arch ring $= 13 \times 71 \times 5\sqrt{2} \times 2\frac{1}{4} \times \frac{1}{36} = 408$ tons.

The thrust upon the front end of the slab is :—

$$\frac{408 \times \sqrt{2}}{2} = 288 \text{ tons.}$$

The water load is that due to the pressure at 155 ft. depth $= \frac{155}{36} = 4{\cdot}3$ tons per square foot.

This, acting on the span of 60 ft., gives per span, or half the load on two spans—

$$4{\cdot}3 \times 60 \times 5\sqrt{2} = 1{,}824 \text{ tons.}$$

The total load is, therefore, $1{,}824 + 288 = 2{,}112$ tons. Then, if b is the width of the slab at the top end where this load comes on it, we have—

$$\frac{2{,}112}{5\sqrt{2} \times b} = \text{the pressure allowed} = 10 \text{ tons per square foot}$$

or—

$$b = \frac{2{,}112}{10 \times 5\sqrt{2}} = 29{\cdot}86, \text{ say } 30 \text{ ft.}$$

The following method may be used to check the whole series of calculations of top end widths—

The weight of the arch ring $= 13 \times 71 \times 5\sqrt{2} \times \frac{1}{16}$.

The component parallel to the layer is—

$$13 \times 71 \times 5\sqrt{2} \times \frac{1}{16} \times \frac{\sqrt{2}}{2} = \frac{13 \times 71 \times 5}{16} = 288 \text{ tons.}$$

The water load is $= \frac{155}{36} \times 60 \times 7{\cdot}07 = 1{,}826$,

total load $= 1{,}826 + 288 = 2114$ (W_1 in Fig. 1),

whence—

$$b = 29{\cdot}99, \text{ say } 30 \text{ ft.}$$

Thus the width of the up-stream end of each slab is calculated.

The next step is to find the width at the foundation for every slab. The thrust in R S F E, for instance, increases as we proceed from R S to F E, owing to the addition of the resolved part of the weight of the masonry above it. If W_2 be the weight of the column of masonry, E G M N F, then the thrust upon the surface represented by E F, and due to this weight, will be $W_2 \times \frac{\sqrt{2}}{2}$, to be added to the resolved part of the arch load and water load. There is another way in which the total load on E F might be computed, namely, by assuming the surfaces of the slabs to be perfectly smooth. In that case the load above a slab would merely hold it down to the slab below, and the load upon the base of a slab would be the resolved part of its own weight. Since the slabs are not smooth the other method is to be preferred, but it may be noted in passing that we get nearly the same results by both methods. The effect of the masonry above any section may be worked out as a pressure for approximate and rapid calculations, but for closer computation the fact that the width decreases towards the top may be taken into account.

Having thus found the proper width for every slab at the base, we next note that, since the water and arch loads remain the same all down the slab, and since, further, the shape and size of the overlying masonry standing vertically above any section in the right-hand half of the figure is the same from the middle vertical, A B, to the base ; *therefore* the area, and the width, of the cross-section of the slab remains the same from where it cuts A B to where it reaches the rock ; so that in the down-stream half of the dam the slabs have parallel sides.

Next consider the portion of a slab between the water face and the middle vertical. It is clear that since the column of masonry above the section halfway, say, is about half the height and considerably less than the mean width of the column vertically above the section at the base to the left of the middle vertical, therefore the increase in width is less than half, and the theoretical slab would, if this were the only

criterion, have slightly concave sides. Actually the sides are made straight, partly for convenience, but also because the concave form would increase the bursting stress at the middle vertical. The shape of each slab is, therefore, found by two calculations, one for each end ; slabs wholly up-stream of the crest having four sides, in plan, and the others having six sides. All these widths are marked in Fig. 1.

To Find the Top End Widths.

Since any underestimate of the weight of the arches or the water load affects the whole length of the corresponding slab of the buttress, it is important that there should be no error on the wrong side at this stage. In the design shown in Fig. 1 a margin of safety was given by taking the length of the arch ring for the calculation of its weight, as 72.6 ft. This gives a sufficient margin to cover the use of a material of somewhat higher specific gravity than $2\frac{1}{4}$, and the making of the arches a little too thick ; further, the margin of safety increases with the depth since the real mean radius of the arch decreases.

The two loads on the up-stream end of a slab are, at any depth, H, and for a thickness, T—

$$\text{water load} = 60 \times 7{\cdot}07 \times \frac{H}{36} = 11{\cdot}78\ H \text{ tons,}$$

$$\text{arch load} = 72{\cdot}6 \times T \times 7{\cdot}07 \times \frac{1}{16} \times \frac{1}{\sqrt{2}} = 22{\cdot}69\ T \text{ tons,}$$

and the—

$$\text{total load} = 11{\cdot}78\ H + 22{\cdot}69\ T.$$

Since the load is equal to the area multiplied by the allowable pressure, and the thickness of the slab = 7.07 ft., we get the equation—

$$\begin{aligned} 11{\cdot}78\ H + 22{\cdot}69\ T &= 7{\cdot}07 \times x \times 10 \\ &= 70{\cdot}7\,x. \end{aligned}$$

For instance, for the slab marked " 28 " in Fig. 1—

$$H = 147\tfrac{1}{2} \text{ ft.}$$
$$T = 12 \text{ ft.}$$

and—

$$11{\cdot}78 \times 147{\cdot}5 + 22{\cdot}69 \times 12 = 70{\cdot}7\,x.$$

$$\text{Whence } x = 28{\cdot}4.$$

We have taken the water load at the springing of the arch, and can safely make this width 28 ft.

To Find the Bottom Widths.

The next, and last step, is to find the widths at the bottom ends of the slabs. Take the slab R S F E, the loads acting on the cross-sectional area represented by F E are—

(1) The water load, 11·78 H;

(2) The arch load, 22·69 T; and

(3) The resolved part, in a direction parallel to the slab, of the column of masonry standing on the two surfaces G E and E F, shown in section in Fig. 5.

Let z be the height of this masonry column and let x, already found, be the top width of the slab, and y the required bottom width.

The thickness of the column is 10 ft., and the weight of the column—

$$= \frac{1}{2}(x + y) \times 10 \times \frac{z}{16} \text{ tons.}$$

The resolved part—

$$= \frac{\sqrt{2}}{2} \times \frac{1}{2} \times (x + y) \times 10 \times \frac{z}{16} \text{ tons}$$

$$= 0{\cdot}22z\,(x + y) \text{ tons.}$$

The sum of the loads on E F—

$$= 11{\cdot}78\text{ H} + 22{\cdot}69\text{ T} + 0{\cdot}22\,z\,(x + y) \text{ tons,}$$

and this total load must give a pressure on the element of base, E F, not greater than the maximum, in this case 10 tons per square foot. Whence we derive—

$$11{\cdot}78\text{ H} + 22{\cdot}69\text{ T} + 0{\cdot}22\,z\,(x + y) = 7{\cdot}07y \times 10.$$

For instance, take the element of base marked "57" in Fig. 1—

$$\text{H} = 110 \quad x = 7 \quad \text{T} = 8 \quad \text{and} \quad z = 180.$$

$$70{\cdot}7y = 11{\cdot}78 \times 110 + 22{\cdot}69 \times 8 + 0{\cdot}22 \times 180\,(y + 7).$$

$$= 1295{\cdot}8 + 181{\cdot}52 + 39{\cdot}6\,(y + 7).$$

$$= 39{\cdot}6y + 1754{\cdot}52.$$

Whence—

$$y = 57 \text{ ft.}$$

The Cross Wall.

Since the width of a slab increases from the top end to the middle vertical, A B, Fig. 1, and is parallel for the rest of its length, there will be a small outward thrust in each slab where it crosses the middle vertical. Fig. 6 shows how this may be calculated. If the arrows *a b* and *a c* represent the thrust at this cross-section, the resultant, *a d*, or, actually, some fraction of it, is the outward thrust in a direction parallel to the water face.

This thrust, for each layer, being plotted, the cross-section of the necessary cross wall, as shown in Fig. 2, can readily be calculated. Such a wall is built between each pair of buttresses, under the crest. When the material of the dam is concrete the same calculations of outward thrusts may be used to determine the amount of reinforcement needed as an equivalent to the cross wall. Such reinforcement, transverse steel rods, may, on account of the special purpose which it serves, be regarded as a reasonable device in a dam otherwise built of plain masonry. The minimum quantity should be used, because if any weakness were afterwards shown a cross wall could be added.

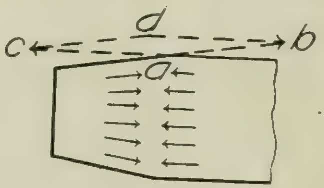


Fig. 6.

Some Further Points.

In order that the dam may be stressed in the manner intended, it is important that the base shall consist of inclined faces, one set parallel to the buttress slabs and the other set parallel to the water face.

As regards the position of the top end of each buttress, the increasing thicknesses of arch rings and

buttress slabs result in these surfaces being at distances from the water face varying from $24\frac{1}{2}$ ft. to $15\frac{1}{2}$ ft. in the design shown here. The effect of this is shown in Fig. 2, to show the extent of the local adjustments needed. In some cases there will be no objection to building a small part of a slab resting upon the arch ring below it. With other materials, or to suit a different order in the placing of materials, it may be preferred to make each slab rest wholly on the slab below it, with the result that the water face will be stepped. This slightly flattens the slope from base to crest, and adds a little to the size of the buttress, since it involves its being taken a little farther downstream.

NINETEENTH ORDINARY GENERAL MEETING

THURSDAY, OCTOBER 26, 1911

THE NINETEENTH ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held in the Lecture Hall at Denison House, 296, Vauxhall Bridge Road, Westminster, S.W., on Thursday, October 26, 1911, at 8 p.m.,

SIR HENRY TANNER, C.B., I.S.O., F.R.I.B.A., F.S.I., etc. (President), in the Chair.

THE CHAIRMAN (SIR HENRY TANNER) :—Gentlemen, we have called this special meeting to-night because we had an opportunity of hearing Mr. Humphrey, of Philadelphia, the Secretary of the Joint Committee on Concrete and Reinforced Concrete of America, and we therefore thought that rather than lose this opportunity we had better call an irregular meeting in order that we might hear what he had to say on this question of fireproofing. I feel sure you all would wish to listen to him and see the slides which he proposes to show you.

MR. RICHARD L. HUMPHREY then delivered his lecture as follows :—

FIREPROOFING.

By RICHARD L. HUMPHREY, M.Inst.C.E., M.Am.Soc.C.E., President, National Association of Cement Users, Philadelphia, Pa.

It would seem rather an interesting proposition for an American to come to Europe and speak on the subject of fireproofing, as the conditions in America are so notoriously bad, and give it, as is well known,

the unenviable distinction of having the greatest fire losses in the world. These annual losses in America are enormous, each succeeding year showing no appreciable decrease. Where the *per capita* losses in Europe are reckoned in cents, those in America are reckoned in dollars, and represent ten times the average loss in Europe. It would seem, therefore, rather incongruous for an American to speak on the subject of fireproofing in a country that has especially low fire losses. However, the occurrence of such enormous losses in America has led to the study of the subject of fireproofing and fire prevention, and of necessity ways and means have been sought to prevent the enormous annual destruction of building materials by fire.

In Europe, where the losses are low, the question is not by any means so urgent, and perhaps does not receive the same attention as in America. Nevertheless, observation of the conditions in America and Europe leads unquestionably to the conclusion that while they are not the same, it behoves, not only England but all the countries of Europe to study the question of fireproofing, and to study it seriously. While it is true there is no annual *per capita* loss of two or three dollars, nevertheless there is no reason for any loss at all, and the mere fact that the losses are much greater in America is no reason for self-satisfaction and absence of efforts to prevent the existing losses. That such efforts are necessary is evident from the fact that in Europe the growing tendency to concentrate enormous stocks of merchandise in buildings is developing a hazard which is as great a menace as it is in America.

There are in the history of countries three great epochs in building construction. The primitive savage required some sort of shelter and erected a structure of whatever materials were available. As the number of structures increased some regard was paid to the necessary sanitary conditions, and the ultimate development into great cities necessitated rules and regulations, not only as regards the safety of the structure itself but also to provide against the loss of life by fire.

This country is blessed with an abundance of slate and stone, and the buildings, therefore, have stone

walls and slate roofs. In America there was an abundant supply of lumber, therefore the earlier

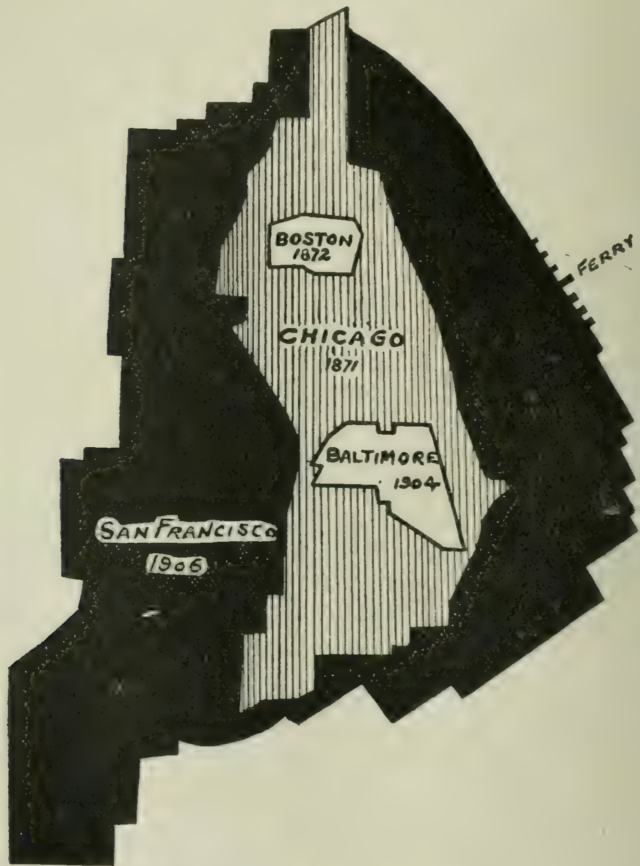


FIG. 1.—Comparative Area of Four Great Fires :—

Chicago	October 9, 1871	2,125 acres
Boston	November 9, 1872	65 ,,
Baltimore	February 7, 1904	140 ,,
San Francisco	April 18, 1906	2,630 ,,

settlers built structures of wood, which practice continued until more permanent construction became necessary. Such permanent buildings, however, were

surrounded by these inflammable structures, which, in time of conflagration, served as a means for their destruction. Throughout America there are numerous illustrations of small towns wiped out in the course of a day, or perhaps a few hours, by reason of these wooden structures.

The construction of buildings always involves the question of economy. Fortunately, in America the increasing scarcity of lumber and the increasing cheapness of concrete has led in a large measure to the elimination of these flimsy buildings, so in time probably the hazard existing in so many cities will be removed.

The subject of fireproofing can best be discussed by considering the various features in the construction of "fireproof buildings," or buildings of high fire-resistance, for no building is absolutely fireproof. The term "fireproof building" used so generally in America is a dangerous appellation, as it instils in the minds of the occupants a false sense of security that often leads to a neglect of those simple precautions which are so necessary, and which, if the building were labelled "non-fireproof," would be carefully observed. Europe believes it necessary to erect buildings of high fire-resistance, and to provide a means for putting out a fire of its contents. In direct contrast to European practice, in America under the lax building laws generally promulgated, buildings of a low fire-resistance are erected, the fire departments are equipped with magnificent fire-fighting appliances, high-pressure water systems, and the country is subjected to a great annual tax for the maintenance of these expensive fire-fighting systems.

The annual losses are not by any means represented by the destruction of property. In addition, there is the annual tax for the upkeep of the fire-protection service, and the additional tax caused by the very high rates of insurance; so that, year by year, the total annual losses from fire, which are believed to be entirely preventable, are represented by a great deal more than the two or three dollars *per capita*, which is merely the value of the property destroyed.

It is most regrettable that this property once destroyed represents a permanent destruction—the

lumber and other materials that go into the building are permanently destroyed, and in America, where the question of the conservation of the natural resources is receiving so much careful attention it is felt of the utmost importance to study the conservation of building materials. There is a great tendency throughout America to revise the building laws for the purpose of ensuring the erection of better structures. Of course, it is impossible to make such laws wholly retroactive, and there must necessarily exist

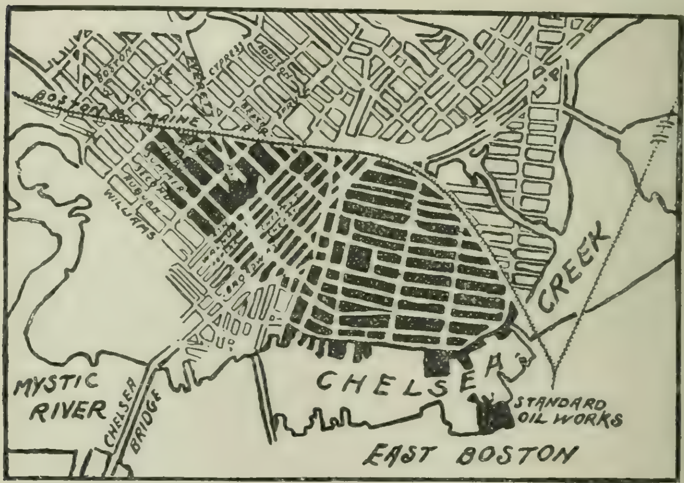


FIG. 2.—The Conflagration, Chelsea, Mass.

for many years to come buildings which at best can only be described as tinder-boxes.

Another important point is the degree of fire-resistance. This resistance may be reasonably sufficient for ordinary conditions, but wholly inadequate against the intense heat from the combustion of a great quantity of inflammable materials that may be stored in it. The growing tendency to store masses of merchandise in buildings makes necessary buildings of higher fire-resistance. On the speaker's visits through Europe he found instances of such fires in buildings ; in one case a great warehouse with a large quantity of cotton

and other similar merchandise had been destroyed. The building itself was reasonably fire-resisting, but insufficient successfully to withstand the intense heat generated by the combustion of its contents. It is evident, therefore, that buildings, as regards their fire-resistance, must be designed with due consideration as to the character of their contents.

CONFLAGRATIONS.

The extent of the great conflagrations in San Francisco, Chicago, Baltimore, and Boston is shown by Fig. 1. The early destruction of the water mains by the earthquake crippled the fire service, leaving the city at the mercy of the flames, which, with the strong wind that was blowing, swept the city, the resident section of which was almost entirely composed of frame structures. The helpless condition of San Francisco following the destruction of the water mains was due to the fact that there was no auxiliary water supply from the harbour. Most of the cast-iron mains were placed in loose soil, and under the shaking of the earthquake were readily broken, thereby putting the entire water supply out of service. This condition has been remedied by the construction of pumping stations along the harbour, which will be entirely free from damage from earthquakes.

Fig. 2 is a view of the town of Chelsea, Mass., introduced to show how in a few hours the business part of a town of considerable size can be entirely destroyed. This town consisted largely of frame structures, with a few buildings of good construction. A strong wind was blowing at the time of the fire, which destroyed about one and a half million dollars worth of property in the course of a very few hours. Fires of this kind, of course, attract temporary notice, but they do not attract the same attention as a great conflagration that sweeps through the heart of a city, and destroys everything except the iron, brick, and other non-burnable materials. A typical view of the result of such a fire is shown in Fig. 3.

The city of San Francisco after the fire was a powerful lesson on the inefficiency of many forms of construction in common use in this country. Other

FIG. 3.—View of Portion of Burned Area, San Francisco.

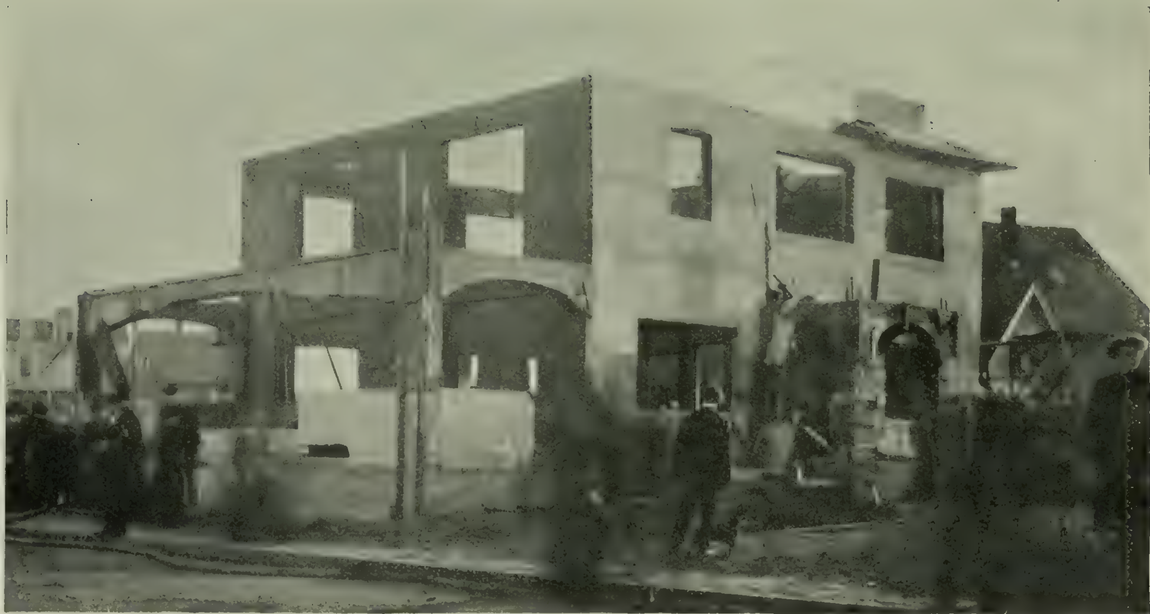


Fig. 4.—Partially Completed Concrete House, Chelsea, Mass. Fire completely destroyed Floors, Roof, Forms, and other Combustible Materials; Concrete unaffected.

great conflagrations have occurred in America, that in Chicago being second to that in San Francisco. While conflagrations of great size occurred in Boston in 1872 and Baltimore in 1904, which destroyed

FIG. 5.—San Francisco Fire. Failure of Cast Iron Exterior Walls.

property worth millions of dollars, they were small in comparison with those of Chicago and San Francisco. In Baltimore the fire-fighting services from Philadelphia, New York, and Washington were practically

powerless, because in the extreme cold weather which prevailed at that time the water supply was of little service. It is interesting to note that it is estimated the San Francisco fire destroyed, in three days, the profits of twenty years in the insurance business.

FIG. 6.—Guarantors Trust Company's Building, Baltimore, Md. Floors and Columns of Reinforced Concrete, Cast Iron Front Enclosure and Brick Side Walls.

It frequently happens after a fire that the walls of a structure are still standing and are taken as an evidence of the fact that the building has satisfactorily passed the conflagration. Often the walls of concrete are not damaged by the fire as in the dwelling-house shown in Fig. 4, which only requires a renewal of floors, doors, windows, and roof to make it habitable again. People looked at that building with its walls of concrete, and said, "Why, it is a first-class fireproof building."

The value of the structure that remained was perhaps 10 or 15 per cent. of the cost of the building—85 or

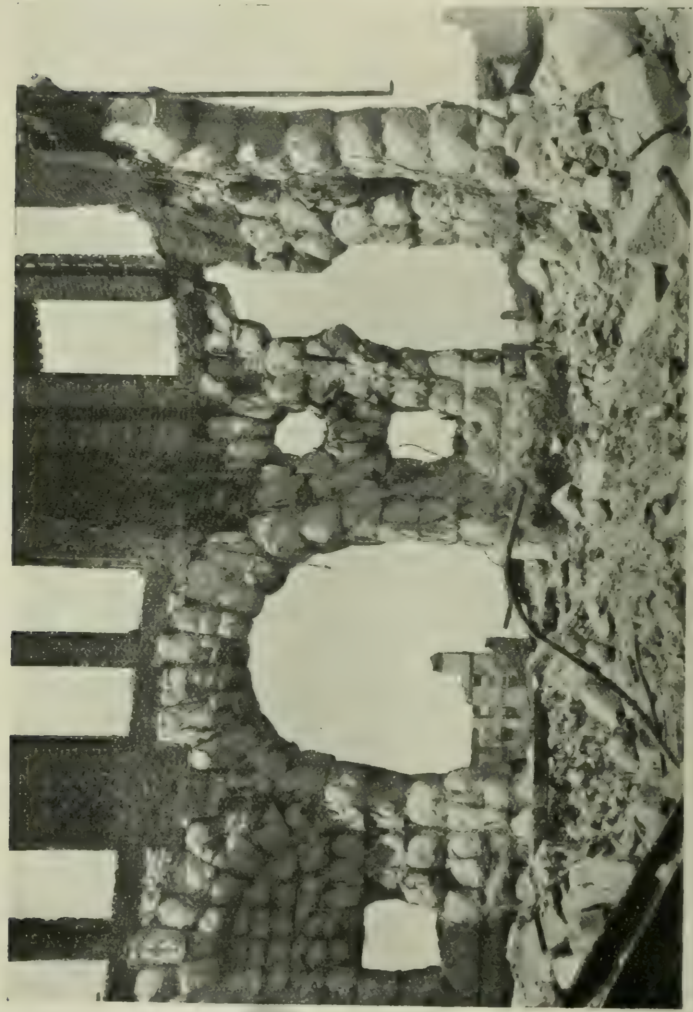


Fig. 7.—Stone Walls almost completely destroyed by Fire.

90 per cent. had been destroyed. It was not the fault of the concrete. The doors, windows, partitions,

floors, and roof were all of wood, and the building, therefore, was far from being "fireproof."

FIG. 8.—Entrance to Ætna Building, San Francisco. So badly damaged by Fire as to have little Value.

Again, the floors and columns often have a reasonable fire-resistance, but the front walls, which are of

cast-iron, are destroyed (see Fig. 5), or the walls of brick wholly or partially collapse. This is illustrated

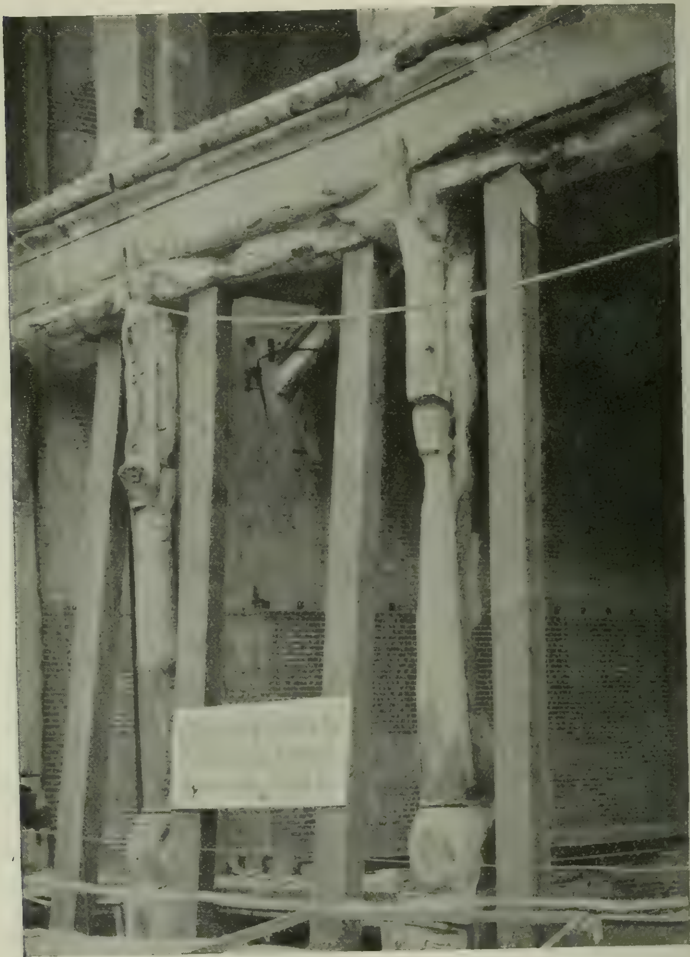


FIG. 9.—Hobart Building, San Francisco. Structural Granite Columns destroyed by Fire.

in the Guarantors Trust Company's building of Baltimore (Fig. 6), one of the best examples in America

of the behaviour of reinforced concrete in a serious conflagration. Load tests were applied to the floors

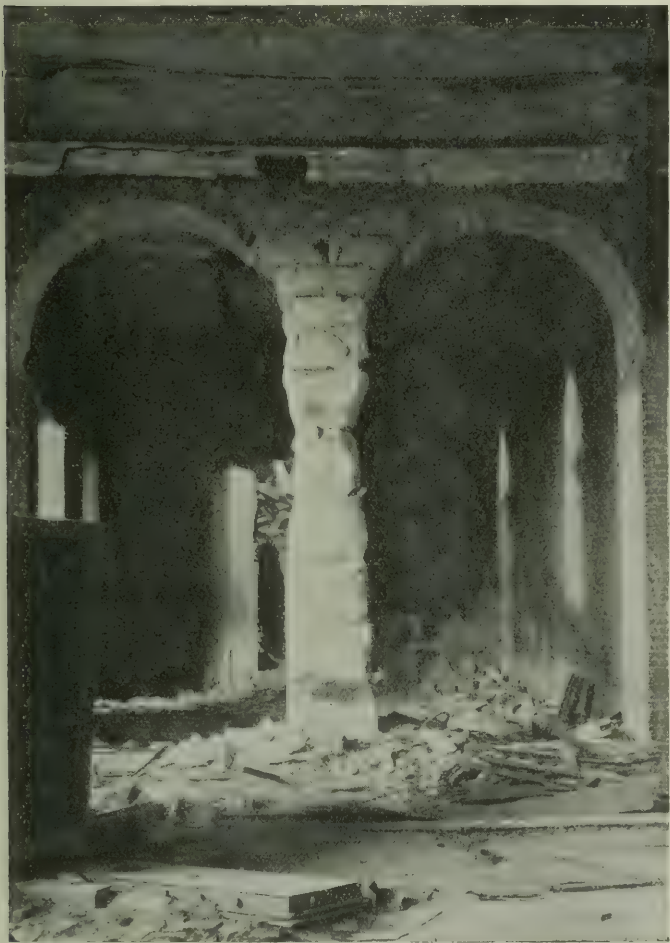


FIG. 10.—City Hall, San Francisco. Interior Column in Treasury Department critically damaged by Fire.

after the fire by the Municipal Department of Buildings, and they were found to be amply safe under the

building laws. In the destruction of the adjoining building by fire an opportunity was afforded for the

FIG. 11.- San Francisco Fire. Collapse of Steelwork from Insufficient Protection against Fire.

construction of an enlarged modern building, and it became necessary, therefore, to tear down this structure

which, although in very good condition, did not fit in with the new structure.

FIG. 12.—San Francisco Fire. Destruction of Light, Unfinished, Unprotected Steel Skeleton by a very moderate Fire of Contents.

FIRE-RESISTANCE OF STONE

Stone is very largely used all over the world for ornamental purposes, and it is evident from a study

of buildings in which a severe fire has occurred that the stone was almost completely destroyed, and could not be replaced without entirely rebuilding the structure. The behaviour of granite and hard, dense sandstone in a fire is ample evidence that the subject of natural building stones should be studied with a view to determining their resistance to fire. The United States Government has undertaken some studies of this kind and has found that the manner in which the stone

FIG. 13.—Cowell Building, San Francisco. The Result of Failure to provide adequate Protection for the Steel Skeleton Against Fire.

is quarried has a material bearing on its fire-resistance. It was found that granite can be so quarried as to offer almost 100 per cent. greater resistance to fire in one direction than it does in the other. It is evident therefrom that in the matter of ornamental building stones there is much to be learned from the point of view of fire-resistance. In a building of this character shown in Fig. 7 the destruction was so extensive as to be practically complete, while the spalling of the exterior granite facing of the Ætna Building (Fig. 8) leaves little of value. When this orna-

mental stone is also a structural member, carrying the exterior walls as shown in Fig. 9, then, of course, the destruction seriously endangers the safety of the structure, and when the main interior columns are of granite their destruction, as illustrated in Fig. 10, is a matter of serious concern, and it shows of what little value a column of this character is as a structural member.

Fig. 14.—Destruction of Reinforced Concrete Floor resulting from Failure from Fire of Unprotected Cast Iron Columns.

If stone is to be used as a structural member of a building, it must be fireproofed just the same as steel or any other material.

Protection of Metal.

In all the great conflagrations in America visited by the speaker, it was a common thing to find buildings of steel, which had not been properly "fireproofed," in the condition shown in Figs. 11, 12, and 13. While steel may have great strength at

normal temperatures, it has little or no strength at high temperatures, and it is evident that steel must

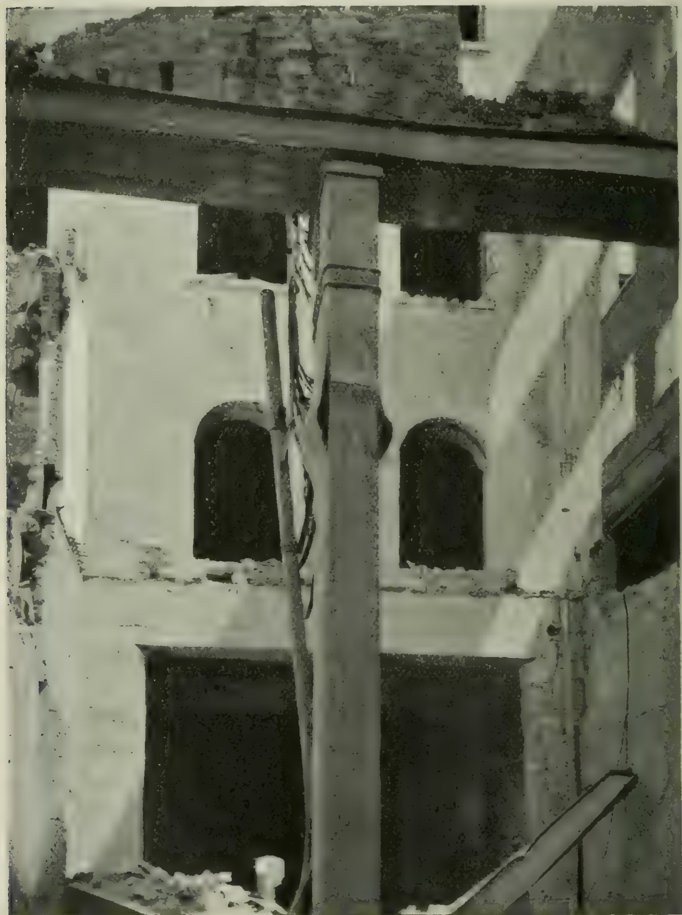


FIG. 15.—Academy of Sciences Building, San Francisco. Complete Failure of Cast Iron Shell. Concrete Core Carrying Load on Column.

be protected from heat. It frequently happens that the floor of a structure may be reasonably fireproof

and constructed properly, but the supports of the floor are of unprotected cast-iron or some equally poor material, and the failure of the supports causes a collapse of the floor. Fig. 14 shows one of the floors of a building which has been particularly cited as a failure of concrete, but naturally these floors of

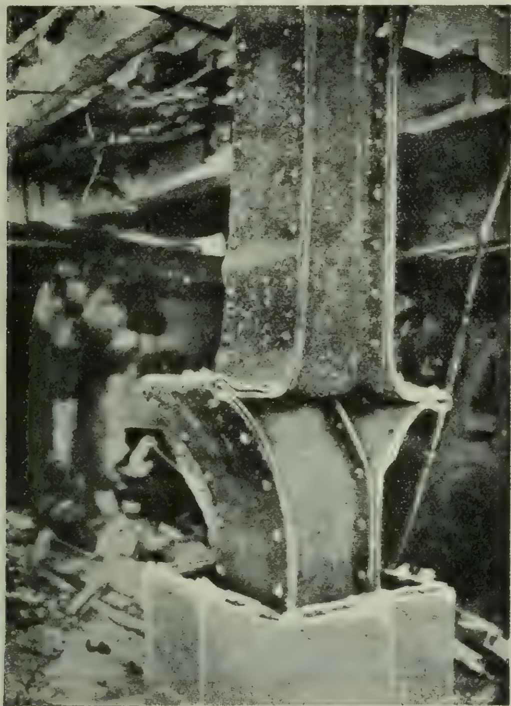


FIG. 16.—Failure of Clay Tile Protection to Steel Column caused a Buckling of Column from Heat.

concrete could not remain in position after the supporting cast-iron columns had failed.

Fig. 15 affords a striking contrast of the relative resistance of two materials to fire. In this particular building, the Academy of Sciences in San Francisco, the architect made a mistake in the calculation of the

size and thickness of the cast-iron columns, and the contractor as a remedy filled the interiors with concrete.

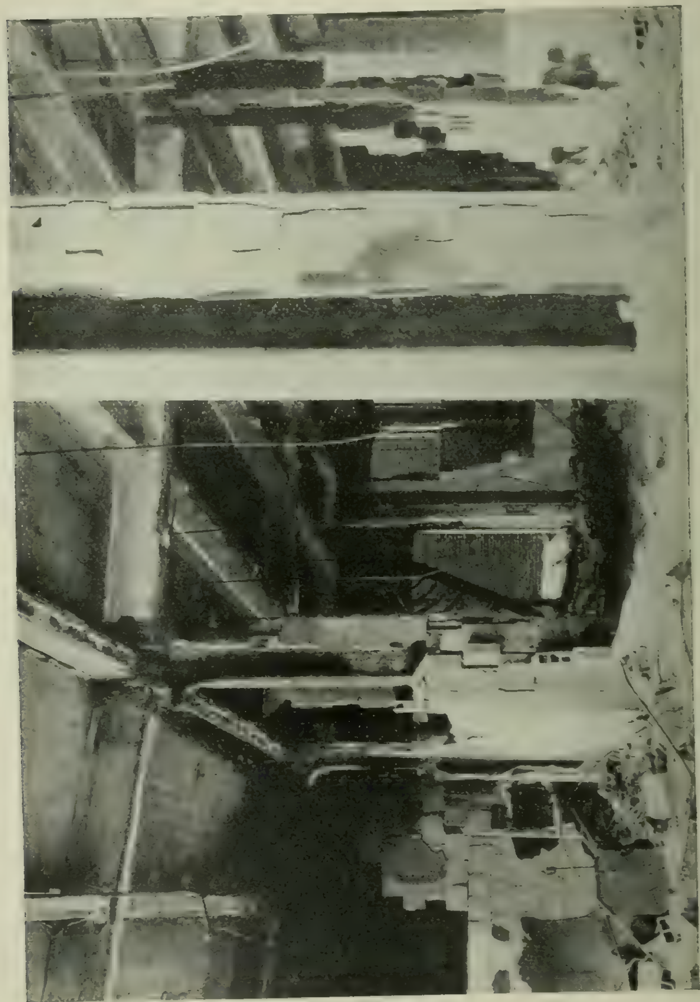


Fig. 17.—Aronson Building, San Francisco. Failure of Clay Tile Protection caused Buckling of Steel Column.

During the San Francisco conflagration the cast-iron expanded under the action of heat, cracked, and failed,

as will be observed, but the load above was carried by the concrete core, which offered greater fire-resistance.

The use of terra-cotta tile represents one of the most common methods of fireproofing in America, and it

FIG. 18.—Buckled Column due to Failure of Wire Mesh Plaster Fireproofing.

is a remarkable fact that architects and constructors in general regard burnt clay as an admirable fire-proofing material. In a large measure this fallacious opinion is based upon the fact that small pieces of burnt fire-clay when heated to incandescence and thrown into water are not disintegrated. But the clay is not

used in that way—it is used in the shape of a hollow tile with thin webs. In the process of manufacture

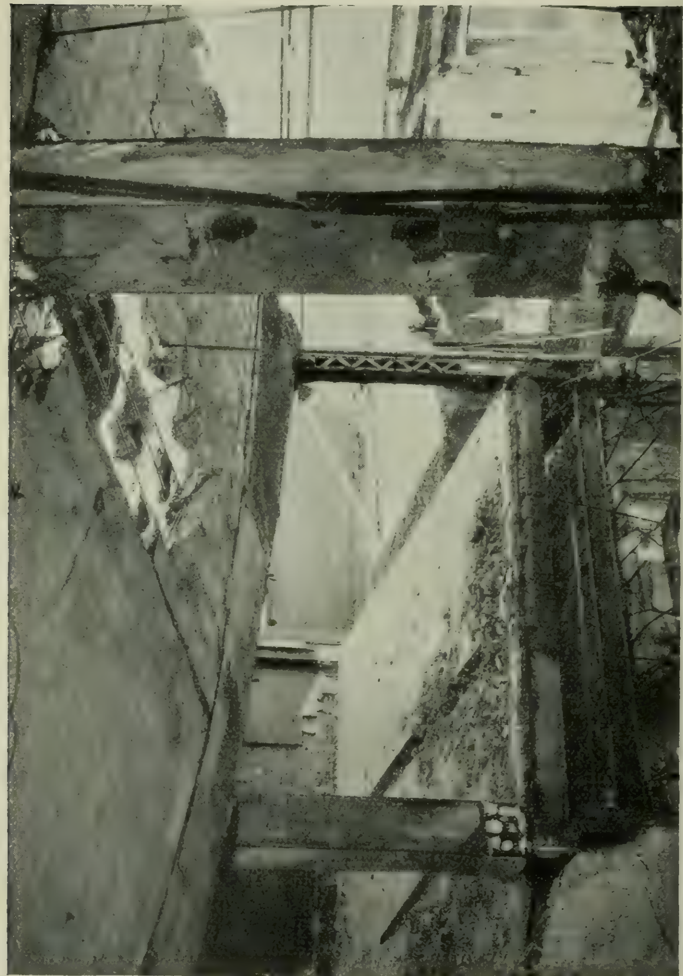


Fig. 19.—Settlement in Floors of Building caused by Buckling from Fire of Insufficiently Protected Columns.

it frequently happens that the webs of these tiles are cracked in the corners, and when columns fireproofed

with clay tile, as shown in Figs. 16 and 17, are subjected to the action of heat, the unequal expansion of the exposed or outer face of the tile and the inner face against the steel causes a tension which the thin webs are unable to resist and they crack and fall off. As a result, the tiles are broken away from the column, which is then exposed to the heat and collapses as shown.

It often happens that in the construction of columns an attempt is made to fireproof by placing around the column a metal fabric which is then plastered

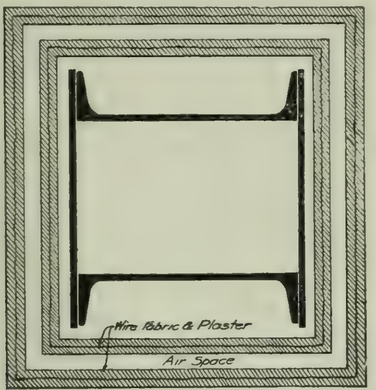


FIG. 20.—A Satisfactory Protection for Columns consisting of a Double Enclosure of Wire Fabric plastered with Portland Cement Mortar.

(Fig. 18). In the Fairmount Hotel about one hundred columns failed as a result of this method of fireproofing. It frequently happened that the floor settled more than a foot (Fig. 19). It must be borne in mind that the heat in the building was not very great as the hotel had not been completed, and the only material burned was a not very large quantity of lumber used in its construction. The burning of this lumber was, however, sufficient to develop enough heat to buckle these flimsily fireproofed columns. A double protection with an air-space between as illustrated in Fig. 20 affords a much more satisfactory protection. It is in the destruction of such buildings that one

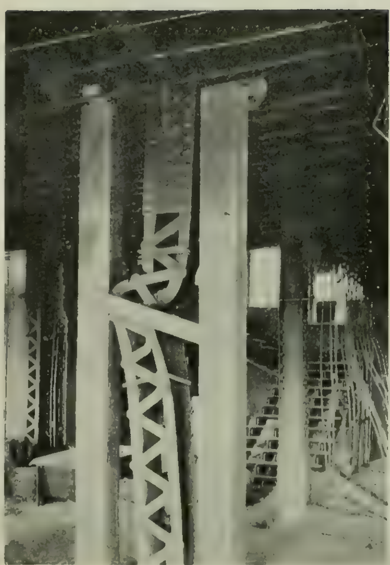


FIG. 21.

FIG. 22.

FIG. 23.

FIGS. 21, 22, 23.—Buckled Columns, Hotel Fairmount, San Francisco. Due to Failure of Metal Lath Gypsum Plastered Fireproofing.

frequently observes the folly of these flimsy evasions of the law (see Figs. 21, 22, and 23).

The method of fireproofing with hollow clay tile,

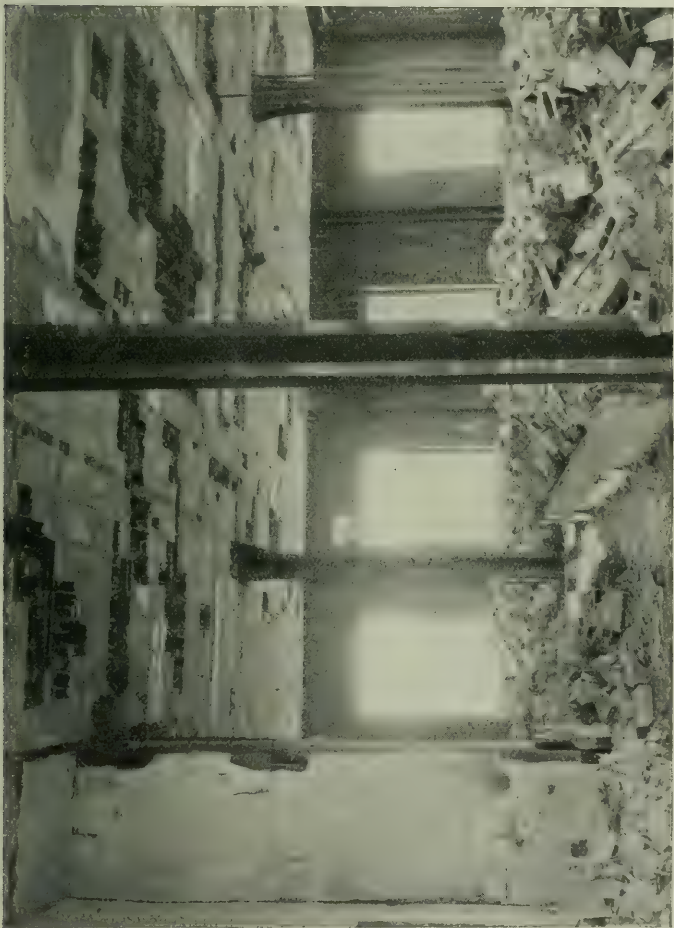


Fig. 24.—Failure of Clay Floor and Partition Tile and Column Protection, Mills Building, San Francisco.

previously described, is illustrated in Fig. 17, in which the columns have been encased with a thin veneer (perhaps 2 or 3 inches thick) of terra-cotta tile.

In this illustration the column has settled 8 or 10 inches by buckling, and the floor above of concrete has been so seriously cracked as to endanger its safety. There was practically no available material in the building after the fire, as the cost of restoring would have been much greater than the cost of entirely rebuilding.

It is quite usual after a fire to find—where terra-cotta tiles have been used—that the lower web has broken

FIG. 25.—Column Failure resulting from the Destruction of the Fireproofing of Wire Lath Plastered with Gypsum.

off by reason of the unequal expansion above described. This is illustrated in Fig. 24, where a large number of tiles, perhaps as much as 35 per cent. of the webs, have failed and fallen off, while a larger per centage are cracked so badly as to be easily pulled off with the fingers. In such a case the only satisfactory remedy in the way of a restoration is the entire reconstruction.

A type of fireproofing for columns which is in quite common use in many cities in America, illustrated in Fig. 25, consists of perhaps one thickness of a

wire mesh, encased with about three-quarters of an inch of ordinary plaster. Between this so-called fireproofing and the column are placed pipes and other metal structures. As may be seen the column has buckled sufficiently to be readily observed; the destruction of the fireproofing is quite rapid. In the case of similar structures one could not tell they had failed except for a slight bulging in the wall, but when the fireproofing was removed as shown, it was found that the column had buckled. In a fire of sufficient intensity, the action of the heat on the plaster is to drive off the water of hydration, leaving an inert

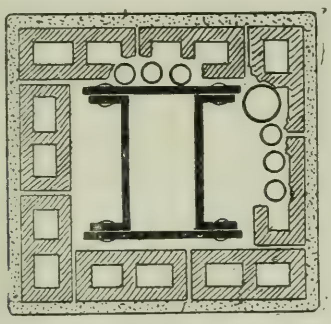


FIG. 26.—Steel Column Fireproofed with Clay Tile Plastered with 1-inch of Mortar. Shows highly objectionable Embedment of Metal Conduits within the Fireproofing.

powder which in itself offers little resistance to the conduction of heat to the steel, and there results expansion and consequent buckling under the superimposed load.

In most building laws, especially the later laws in America, there are strict clauses which prohibit the embedding of pipes and conduits of various kinds in the fireproofing of columns (see Fig. 26). Contractors frequently destroy the efficiency of the fireproofing in order to get pipes and conduits installed (Figs. 27 and 28), by breaking away the web in order that the tile may be fitted around the pipes or conduits which perhaps were not considered when the building was designed. These are not usually discovered until a

fire causes the stripping of the fireproofing, as may be seen in Fig. 29, showing how the webs of the tile in this so-called "fireproof" column failed. In

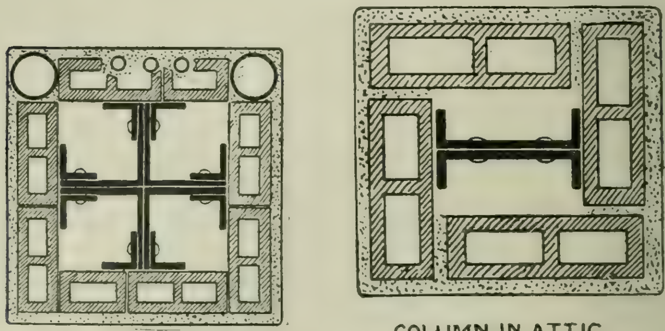


FIG. 27.—Faulty Methods of Locating Metal Conduits, greatly decreasing the Efficiency of the Fire Protection.

Figs. 30 and 31 may be seen the character of work done with hollow tile. The bottom flange of the girder is protected with three-quarters of an inch of

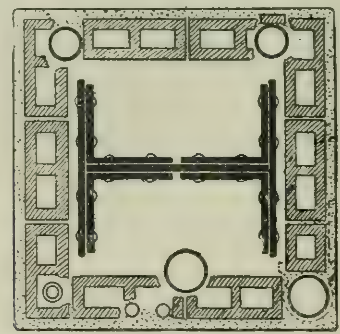


FIG. 28.—Methods of Breaking Clay Tile Fire Protection to care for Metal Conduits, still further destroying the Value of the Poor Fireproofing Material.

solid burnt clay. The effect of heat on such a surface is to destroy the anchor holding the tile in place and the girder or beam buckles from the expansion due

to the heat. The under side of the floor tiles " spall " or split off under the unequal expansion of the exposed web and the upper or protected web. In Fig. 32 the fireproofing is covered with 1 inch of Portland cement

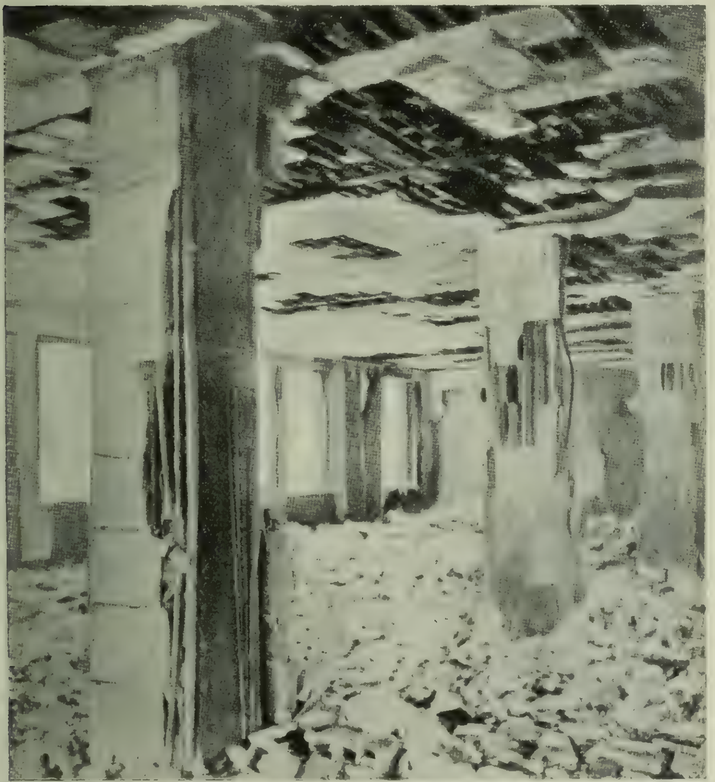


FIG. 29.—Calvert Building, Baltimore Fire. Failure of Clay Floor Tile and the Stripping of Clay Tile Column Protection through Expansion of the Embedded Metal Conduits.

plaster, which is insufficient to equalise the defects in the clay tile protective covering previously referred to. All these methods are flimsy in the extreme, and it is an outrage even to permit them to be classed as

"fireproofing." Fig. 33 illustrates quite clearly the effect of pipes embedded in the fireproofing. The expansion of these pipes has practically stripped the fireproofing from the column. Another great difficulty in this form of construction is the fact that in the burning of these clay tiles it is impossible to get perfect tiles. They not only warp out of shape and crack from shrinkage at the corners where the web

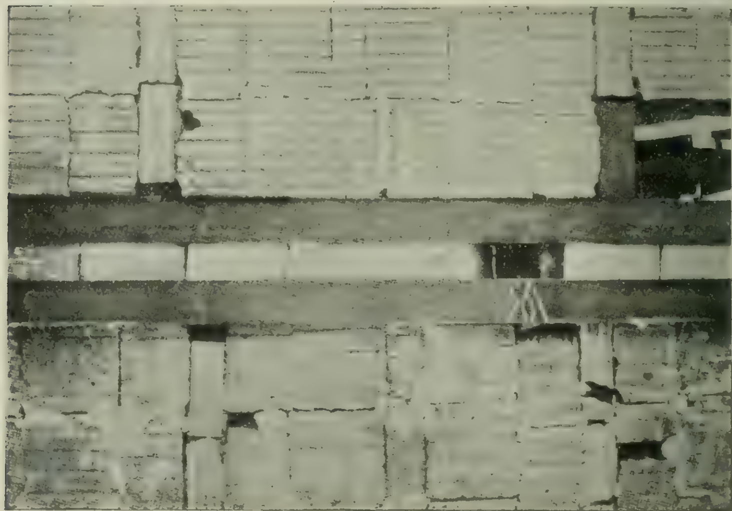


FIG. 30.—Defective Workmanship Destroying the Protection of Steel Girder with Clay Tile.

joins, but it frequently happens that they are broken or otherwise damaged in handling, and the break is very badly covered with a flimsy coating of mortar. The holes are usually covered with perhaps a quarter of an inch of plaster, which either drops off in a fire or readily allows the conduction of heat sufficiently to soften the steel, causing a buckling of the steel and the consequent stripping of the fireproofing from the column.

Attempts are being made to improve this condition, and Fig. 34 shows a column fireproofed with a coating

of 1 inch of Portland cement mortar on the outside. This undoubtedly is a better method of construction. There is also frequent resort to the practice of filling the space between the steel column and the outer tile with concrete—a still better form of fireproofing. Even

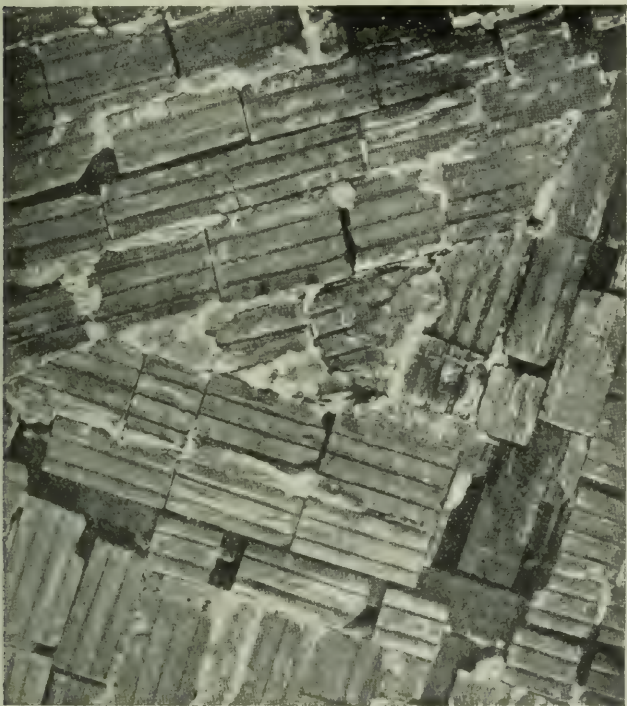


Fig. 31. -Defective Workmanship in Fireproofing with Hollow Clay Tile. Note Broken Tile, Open Joints, and other serious Breaks in Protective Covering.

with these improvements the webs fail, and it frequently happens that this protection of concrete is insufficient in thickness to resist the temperature, and buckling occurs.

The view in Fig. 35 is given to illustrate some of the fallacies among men who apparently are gifted with

reasonable intelligence. Let us suppose that the two columns shown are of identically the same section. The columns were made in long lengths, cut up in 12-foot lengths and tested at definite ages. One column was entirely of concrete, and the other column

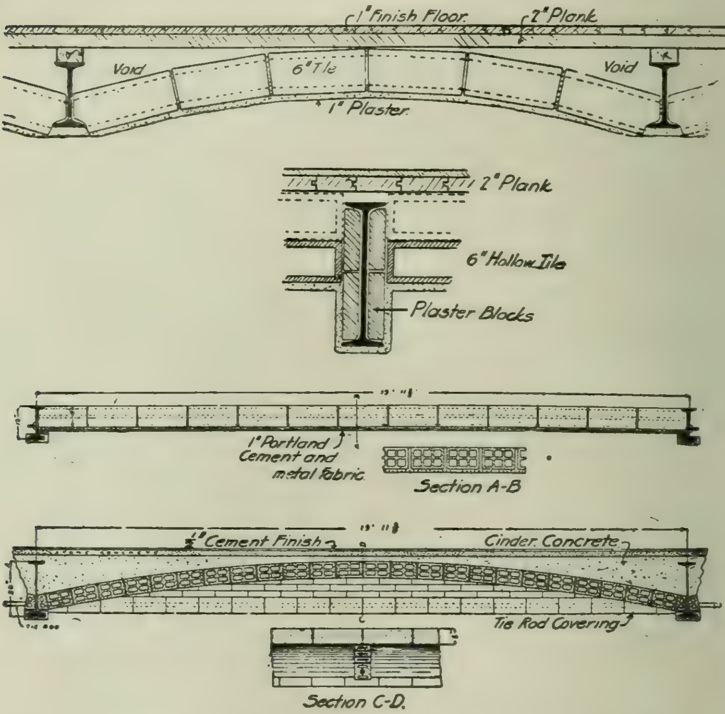


FIG. 32.—Method of using 1 inch of Portland Cement Plaster on Exposed Surface of Clay Tile Fireproofing. Does not Repair Defects in Clay Tile.

had an additional protection of 3 inches of clay tile. The column with the additional protection of clay tile naturally stood a higher load test than the column without the protection; the argument was that the concrete, protected as it was with the 3 inches of clay tile, was the best form of construction there was. As a matter of fact, if they had made the concrete column of the same section as that protected with tile,

they would have had a still better structure, as has been frequently shown. Columns (Fig. 36) with all concrete protection are very much superior as to fire-resistance than those protected with tile and some concrete.

FIG. 33.—Bullock and Jones Building, San Francisco. Effect of Expansion of Embedded Metal Conduits in Stripping Clay Tile Fire-protective Covering from Columns.

In the San Francisco fire one frequently saw (Fig. 37) buckled columns which had resulted in a settlement of the floors from 12 to 18 inches; after the fire it became a problem as to how to repair them. In some buildings jacks were employed to

raise these reinforced concrete floors to their normal position, the buckled columns were cut out, new ones

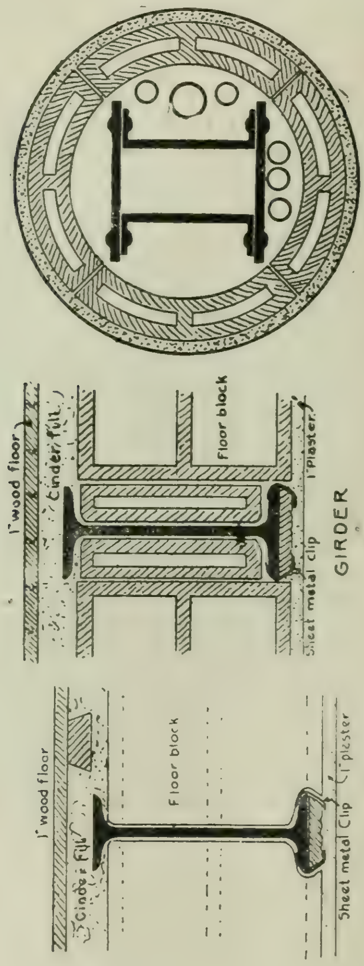


Fig. 3.

Fig. 2.

Fig. 1.

Fig. 34.—Clay Tile Fireproofing covered with 1 inch of Portland Cement Mortar, thereby greatly increasing their Fire Resistance.

put in and fireproofed, and thus repaired were passed by the authorities as being perfectly good. Just what the condition of the floor was after having settled

18 inches, and then being pushed back in position, no one knows.

The floor, of course, is an important part of the structure ; if the columns are reasonably fireproof, it is necessary that the floor shall be fireproof. Fig. 38 illustrates an admirable fire-barrier for the under side of floors which, unfortunately, are not always properly designed. Suspended ceilings, *i.e.*, ceilings suspended from the under side of the floor, in the San Francisco and Baltimore fires proved an excellent shield, and

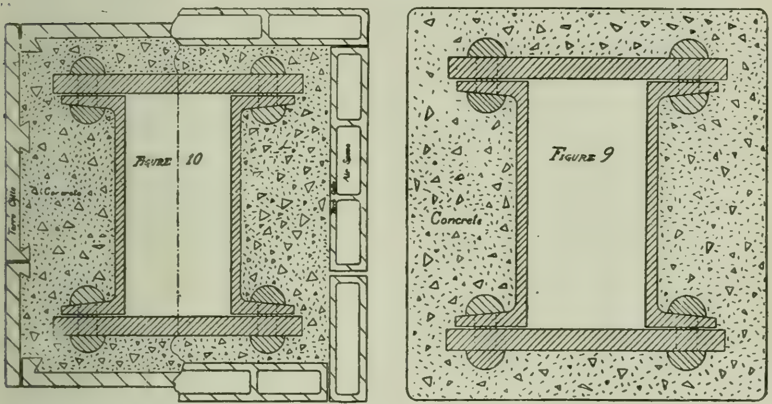


FIG. 35.—Fallacious Method of using Clay Tile and Concrete for Protective Covering. An All-Concrete Protection would be very much better.

greatly increased the fire-resistance of the floor. Unfortunately, in carrying out this idea, it frequently happens that ordinary gypsum plaster is used and the ceiling is held in place by a very flimsy anchor ; the gypsum loses its coherence at a very low temperature, the anchor is destroyed by the heat, and the ceiling falls. In the illustration, Fig. 38, all except the lower flange of the steel beam is protected with concrete ; it will also be noticed that a steel support, backed by concrete, springs from the beams and carries the floor above. A feature that is bad is the fact that the metal anchor which holds the suspended ceiling in place is attached to the steel beam. When

the plaster protection, which is very thin, is destroyed by heat, these anchors or supports become a medium for the conduction of heat to the steel beams, which frequently are heated sufficiently to cause their collapse.

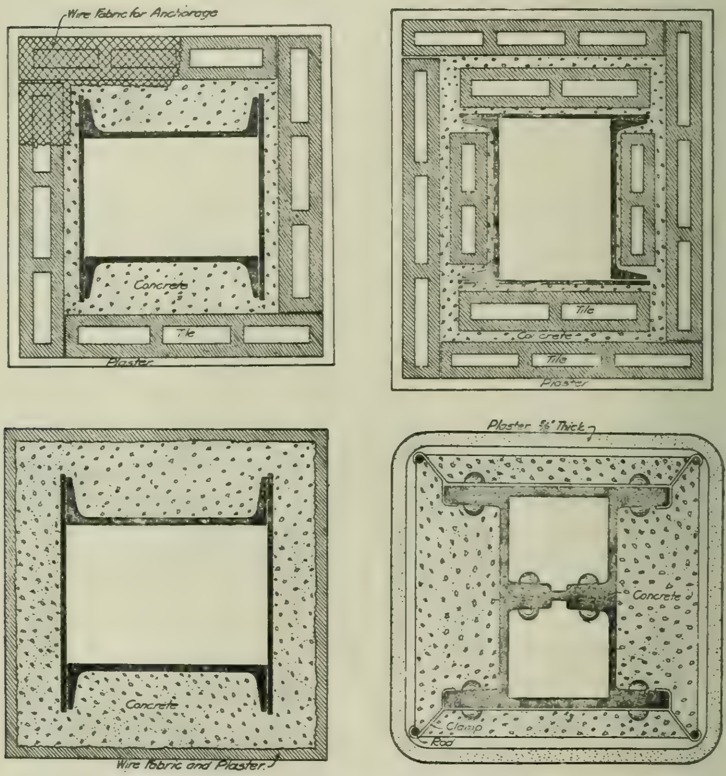


FIG. 36.—Various Methods of combining Clay Tile and Concrete, which are in common use, all-concrete being by far the most efficient with the greatest Fire Resistance.

Fig. 39 is particularly interesting, as the anchors failed and caused a collapse of the suspended ceiling protecting a reinforced concrete floor. This protection was unnecessary and in this case was used to secure a flat ceiling. The fact that the flimsy character

of anchor holding the ceiling in place frequently renders such a barrier inefficient is well illustrated in Fig. 40.

The building shown in Fig. 41 is of reinforced concrete with columns well protected, but the engineer who designed this structure destroyed its efficiency by placing an unprotected band of steel under the rib of concrete. It happened in this particular building,

FIG. 37.—Monadnock Building, San Francisco. Method of Using Jacks to raise Floor to Normal Position for the purpose of replacing Buckled Columns.

which was a warehouse, that there were great quantities of wooden boxes stored there. The heat expanded these bands, causing a collapse of the floor under the superimposed load.

A very common type of construction is shown in Fig. 42, where clay tiles are placed against the side of the girder, and a very thin coating of hard plaster placed over the tile and around the flanges. Of course, as far as the interior decoration of the building is concerned, this is economical and effective, but for fireproofing steel it is of little value. It would be

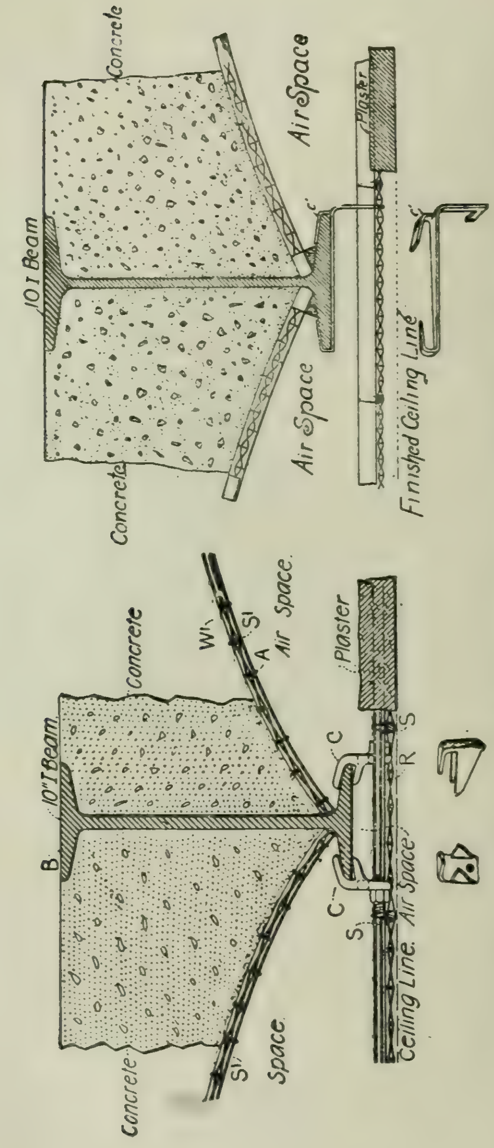


FIG. 38.—Method of attaching a Suspended Ceiling to the Flange of a Beam or Girder.

Fig. 39.—Collapse of a Suspended Ceiling due to Destruction of Metal Anchor by Heat.

better if these steel girders were entirely unprotected, because then the people who occupied the building

FIG. 40.—Failure of a Suspended Ceiling. Illustrates the Inefficiency of this form of Fire Protection when improperly Constructed.

would realize that they were unprotected, and would exercise precaution to avoid a fire in that particular

building. The thin coating of even Portland cement mortar is insufficient protection for the clay tile, and

FIG. 41.—Third Floor, Ætna Building, San Francisco, illustrating defective Floor Design in Exposure of Reinforcing Metal.

their efficiency is still further reduced by the defects in manufacture and handling.

It frequently happens that the girders are protected with a thin coat of plaster supported on an anchor, and the failure of this plaster exposes the steelwork to the heat, causing the consequent destruction of the floor.

Fig. 43 illustrates the inefficiency of this method of fireproofing—the tiles have dropped out through the expansion of the steel girders; and another important

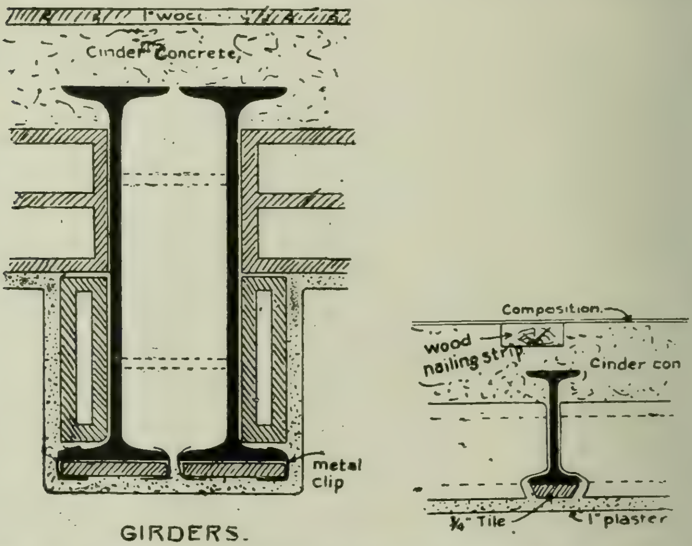


FIG. 42.—Defective Fireproofing of a Girder—commonly used because of Simplicity of Construction for decorative Purposes.

feature in this view is that the wind bracing, which was protected by a thin wall of clay tile, was exposed through the failure of the tile and buckled so seriously as to impair the strength of the building.

It generally happens that the roof trusses of a building are not protected. The upper ceiling is rendered reasonably fireproof, but the steel trusses of the roof are not protected, and as a result (Fig. 44) the roof affords an entry for a fire from the outside, which, through the collapse of the roof trusses, gains access to the building. It is just as necessary to protect the

steelwork of the roof as it is any other part of a structure.

Fig. 45 illustrates another attempt to economise

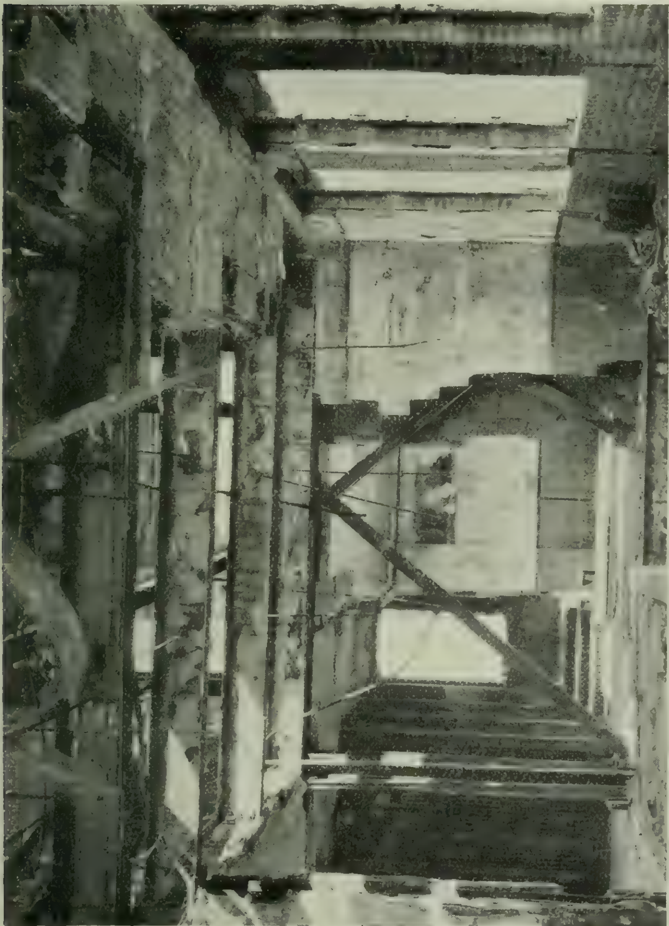


FIG. 43.—Union Trust Company Building, San Francisco. Failure of hollow Clay Floor and partition Tile, causing buckling of Beams and Wind Bracing.

in construction; in this case the wood floor rests on the top flange of the steel girders; the destruction of the contents of the room may destroy the wooden

floor and heat the beams sufficiently to cause their destruction.

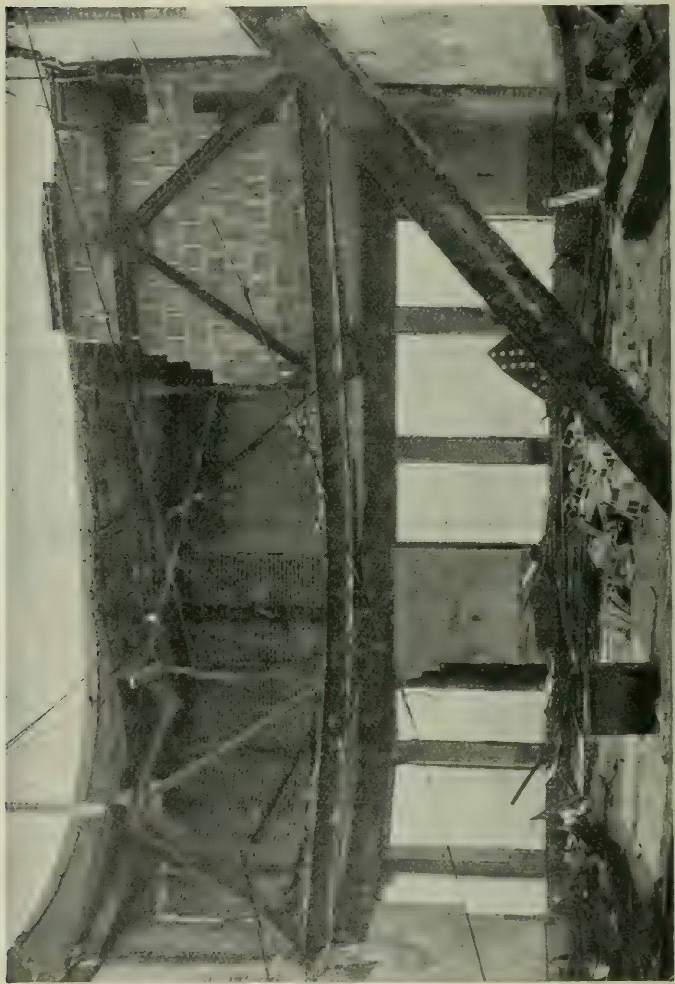


FIG. 44.—Mutual Life Building, San Francisco, Cal. Roof Trusses damaged by Heat through failure of Clay Fire Protection.

In most cities there are to be found buildings of large size having a reasonable fire resistance, and sometimes even monumental in their construction, but they

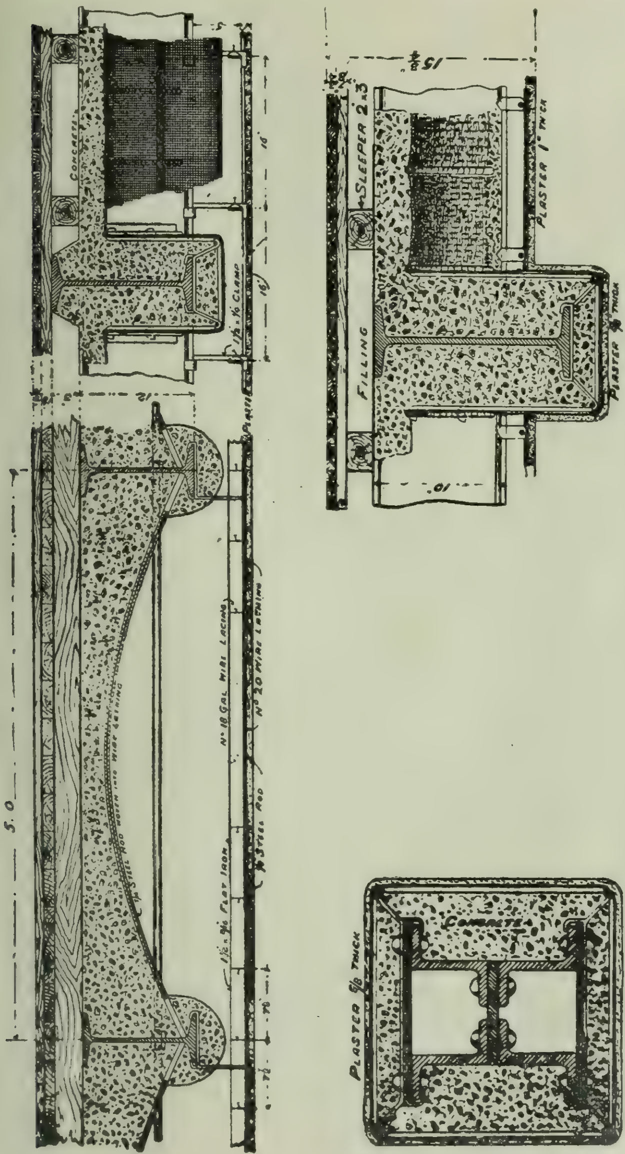


FIG. 45.—Wooden Floor resting directly on steel Girders, thereby rendering them liable to serious Damage through the Destruction of the Floor.

FIG. 46.—Call Building, San Francisco, showing the complete Destruction of Windows by Fire.

are surrounded by "fire traps." This is particularly true in large cities in America, where we have

FIG. 47.—Warping of Metal Lath Partition through Inadequacy of Gypsum Plaster to protect it against Action of Heat.

extremely high buildings which, if they were protected properly with metallic window and door frames and

fire-glass windows, would probably act as a barrier, but with unprotected plain glass and perhaps wooden frames, they offer little or no resistance to a fire. The destruction of the tinder-boxes surrounding them brings about the destruction of the contents and the buildings themselves.

The building shown in Fig. 46 was notable because it was one of the high buildings of San Francisco. The steelwork was reasonably well fireproofed, but

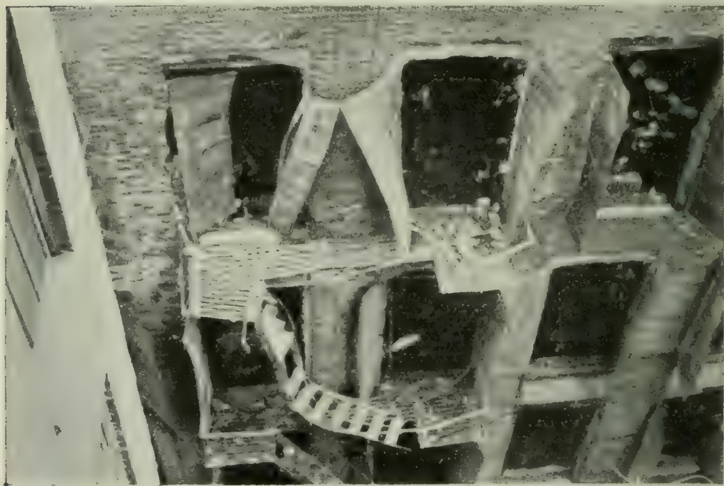


FIG. 48.—Asch Building, New York. Efficiency of the sole " Fire Escape " to this Building.

the windows were plain glass, and the contents caught fire. With the destruction of the contents came the destruction of the fireproofing, and a great deal of damage was done to the steelwork. It is evident from this picture, which shows a common sight after a fire, not only in America but in this country as well, that a building with wooden window frames and plain glass windows is at the mercy of the fire in adjacent buildings. It is a common practice all over the world immediately to break the glass in a building that is on fire to let the air in, so that the firemen can locate

the fire. The bursting forth of the flames from these windows breaks the glass of the windows of the adjoining building, and the fire thus spreads from building to building. In this way large areas are destroyed in America, simply because the buildings themselves are not protected against fire from without. And in the buildings themselves you frequently find that the floor areas are insufficiently divided up. This is not true in England and the Continent, where substantial masonry walls divide up the floor into comparatively small areas, which is a commendable feature; but in America there are frequently large areas entirely unbroken by fire-walls, and if the walls occur they are commonly of very low fire-resistance, often consisting of metal fabric with a very thin coating of plaster-of-Paris. Such a type of partition is illustrated in Fig 47, from which it is evident just how fire-resistant a partition of that kind is, especially in a building filled with a large quantity of inflammable goods. This particular partition encased the stairway of the building—the means of exit in case of fire.

Similar conditions prevailed in the Asch Building fire in New York, where the occupants of the upper floors, finding that they could not use the fire-escape (Fig. 48) on account of the flames, and could not go down on the elevators because the doors leading to them were either locked or blocked with machinery, jumped out of the windows 100 feet to the street below. It was a case of death, and many chose the quicker method. It is interesting to note that the impact of the falling bodies from that ten-story building punched a hole in the vault light of the pavement. This fire has occasioned a great deal of controversy and discussion, particularly in New York. Many indignation meetings have been held, and spasmodic efforts made to revise the New York building laws; the dreadful conditions surrounding the Asch Building were thoroughly ventilated in the technical and local press. But it is a significant fact that, standing on the pavement of that ill-fated Asch Building, one can see within a stone's throw many more buildings that are infinitely worse as regards the construction and provisions for safety in case of fire than the building in which this catastrophe occurred.

It is not only necessary that the floors and columns of a building shall be properly protected against fire,

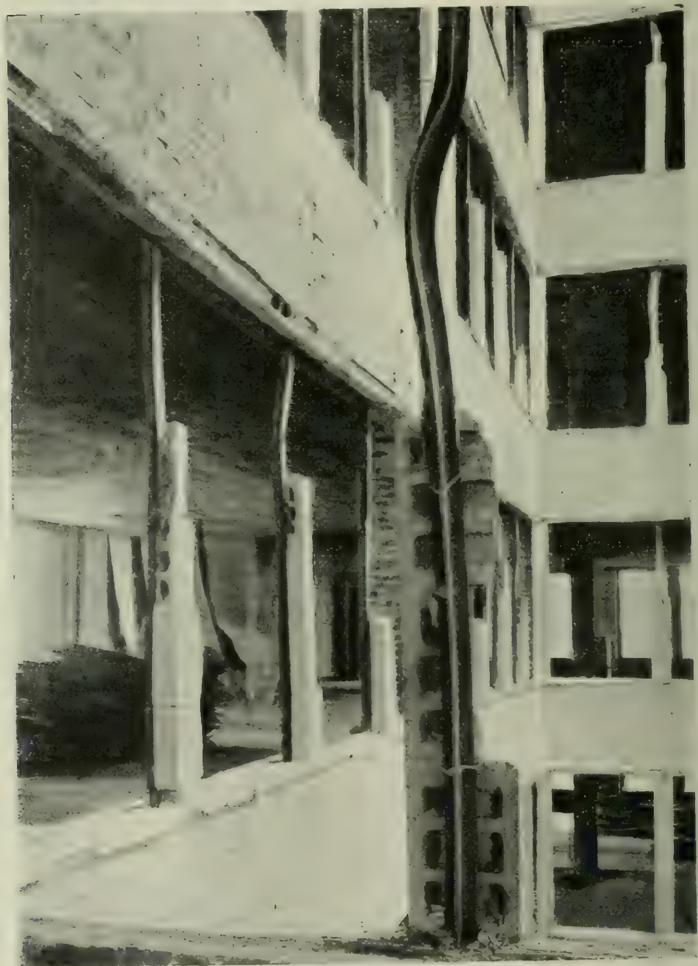


FIG. 49.—Merchants' Exchange Building, San Francisco. Spalling of Enamelled Brick Facing of Light Well and Failure of Clay-Tile Fireproofing of Window Frame Separator.

but it is also necessary that the exterior exposures shall be protected. It frequently happens (Fig. 49)

FIG. 50.—Wells-Fargo Building, San Francisco. Light Well, showing Failure of Plain Glass in metal Window Frames.

that the windows are of metal frames protected with clay tile or some similar fireproofing, and the destruction of these windows affords easy access for the flames to spread from floor to floor, and leads to the destruction of the building.

Fig. 50 is a view of the light well, Wells-Fargo

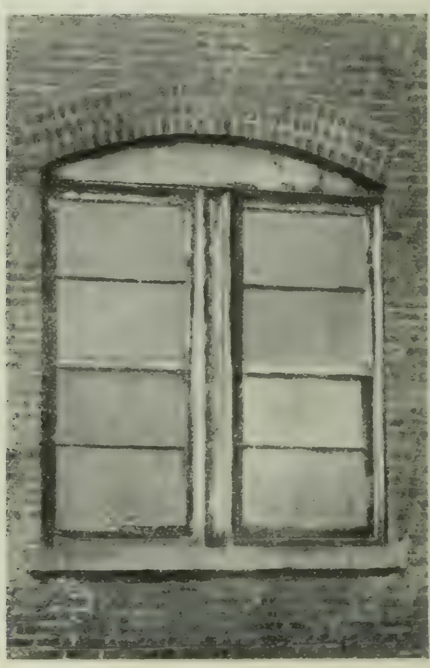


FIG. 51.—An excellent Type of Fire Barrier from Exterior Fires: Metal Frame with Wire-Glass.

Building in San Francisco, where metal frame doors and windows with plain glass were used, and under the action of the heat the glass simply softened and fell down, as may be seen. Of course, this barrier was of little value. On the other hand, when the window is constructed with metal frame and wire-glass of approved type, the glass often softens but remains in place, and thus prevents the fire from gaining

access to the building. Such a type of window is shown in Fig. 51, being that of a building adjoining one of poor construction, which was entirely destroyed; the excellence of this window as a fire barrier prevented the destruction of the contents of that building.

The doors in the view shown in Fig. 52 are provided with roll sashes in front, and whilst the falling

FIG. 52.—Volkman Building, San Francisco. Rolling Fire Doors, Metal Frames, and Wire-glass Windows. An excellent Barrier in this Conflagration. The broken Windows of the first floor caused by the falling Wall of adjacent Building.

walls cracked the glass of these wire-glass windows, nevertheless they proved a sufficient barrier to prevent the entrance of the flames into the building itself.

Fig. 53 is a view of the Pacific States Telephone and City Telegraph Building in San Francisco. The building was excellent construction, with reinforced concrete floors and columns. The exterior was protected with metal shutters, metal frame windows, and wire glass, but, as too often happens, it had a weak

Fig. 53.—Pacific States Telephone and City Telegram Building, San Francisco. A Building of very high Exterior and Interior Fire Resistance.

point. The door in the rear of the building was unprotected, and the destruction of that door by the

FIG. 54.—Building with Metal Frames and Wire-glass Windows undamaged by Fire in adjoining Building.

fire of the surrounding buildings enabled the flames to enter, and wrought partial destruction of the contents, from which it is evident that all parts of the

building must be equally fireproof. It is not sufficient that three-quarters of the building shall be immune

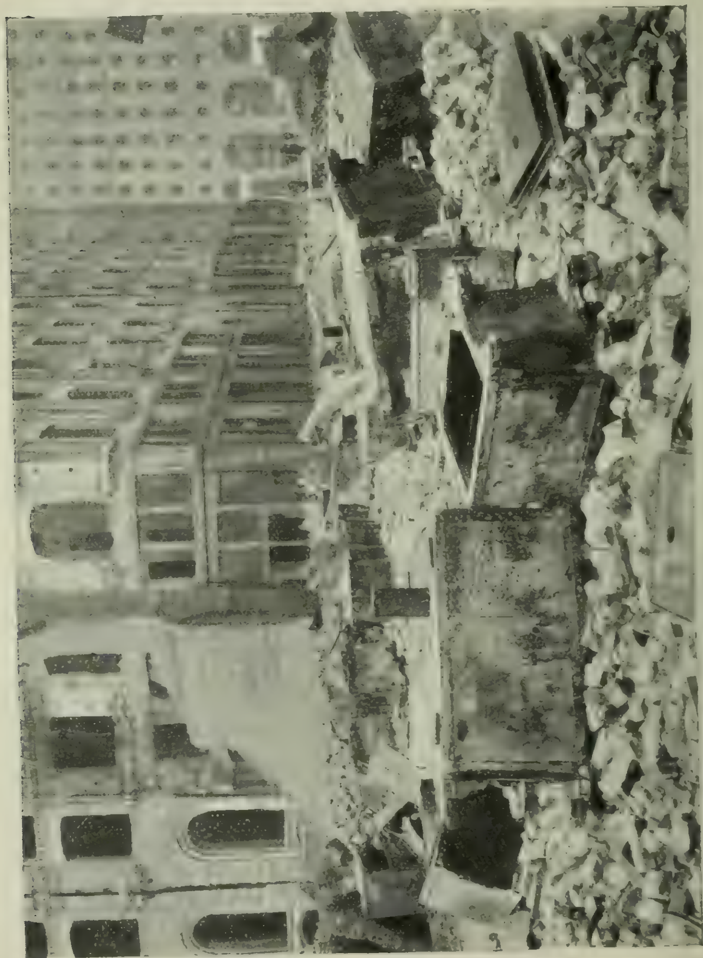


FIG. 55.—Fifty so-called "Fireproof Safes" in rear of Palace Hotel, San Francisco.

from damage from outside, but all the building must be properly protected.

Fig. 54 is a building of reinforced concrete, with metal-covered door and window frames and wire-glass

windows, which stood undamaged amid the destruction of the surrounding buildings.

Figs 55 and 56 are interesting views of the result

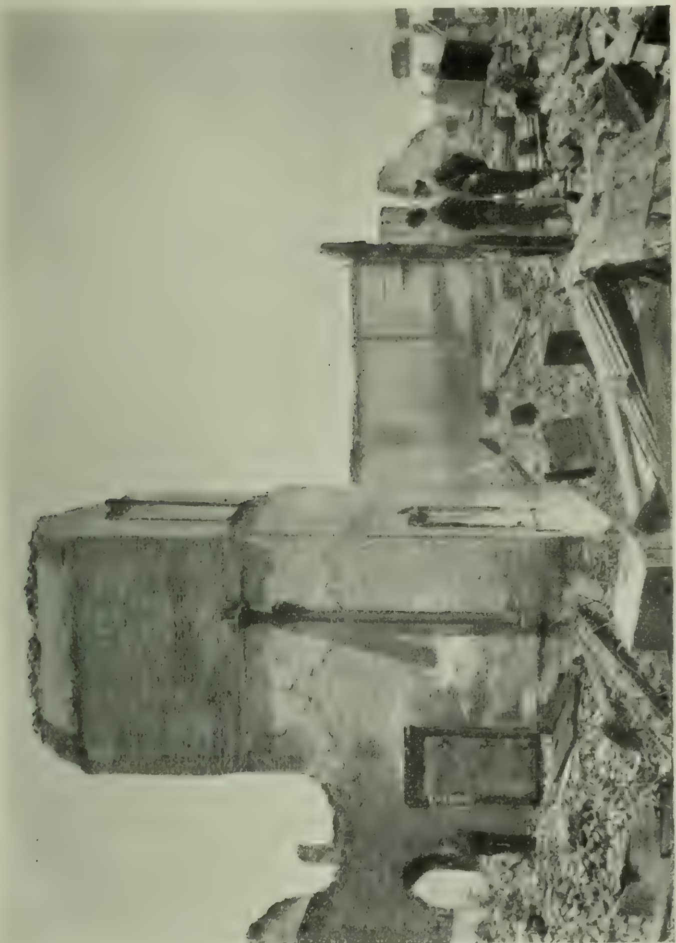


Fig. 56.—Brick Vault in the Wells-Fargo Building, San Francisco, which satisfactorily protected its Contents from Fire.

of different methods of protecting valuable papers and records from destruction by fire. Fig. 55 shows about fifty so-called "fireproof" safes in the rear of the

Palace Hotel, San Francisco, whose contents were uninjured. Great care must be exercised in reducing the temperature of the interior to that of the exterior. Otherwise the contents may be destroyed as the result of spontaneous combustion. Concrete vaults have an equal if not higher fire-resistance than brick vaults, which are the best types. Excellent fireproofs, consisting of concrete-filled metal safes, are second only to the concrete vault.

FIG. 57.—Mills Building, San Francisco, interior completely destroyed by Fire standing on Shell much damaged.

A few words in connection with the general question of fireproofing. It has been illustrated how columns, floors, and windows should be properly protected to resist fire from within and to prevent the entrance of fire from without. There is no doubt of the tendency to-day, with the development of great business enterprises, to erect enormous warehouses. Even where the laws of the country tend to limit unbroken floor areas there is also a tendency to concentrate in buildings inflammable merchandise in large quantity.

In Europe an effort is made to build fireproof buildings, and then have an efficient fire service that can go quickly to a fire and extinguish it almost as soon as it occurs ; this would seem the ideal condition.

Another matter in which America is interested is that of the conservation of human lives. Much greater regard is had for life in this country and on the Continent than in America. Each great conflagration or fire in America becomes a greater or lesser holocaust in proportion to the number of lives lost. Little consideration is given to the matter of safety appliances or to providing facilities for the escape of occupants of a building in case of fire. This is particularly true in the case of theatres, schools, and other places of public assembly. Pertaining to the subject under discussion is the provision of safety appliances and facilities for the escape of the occupants of a building in the case of fire, which might be classified as follows :—

1. Iron fire-escapes.
2. Encased stairways.
3. Stairway towers.
4. Encased fire-towers.
5. Serviceability and capacity of exits.
6. Spiral chutes.

1. *Iron Fire-escapes.*—These contrivances consist essentially of steep iron ladders with narrow iron treads of such a character that even under ordinary conditions it is almost impossible for any one to descend with any degree of speed without serious danger of falling. They are generally placed on the exterior of the building, passing unprotected plain glass windows, which readily become an outlet for the flames, thus putting the "fire-escape" out of commission. As previously stated, such was the condition in the Asch Building fire, and rendered the escape of the occupants of the upper floors impossible. Fig. 48 clearly shows the flimsy character of this structure, rendered useless by the flames from the windows surrounding it.

Fortunately, continual ridicule of these ill-conceived contrivances is having its effect in that they are rapidly becoming obsolete, and it is the hope of those who

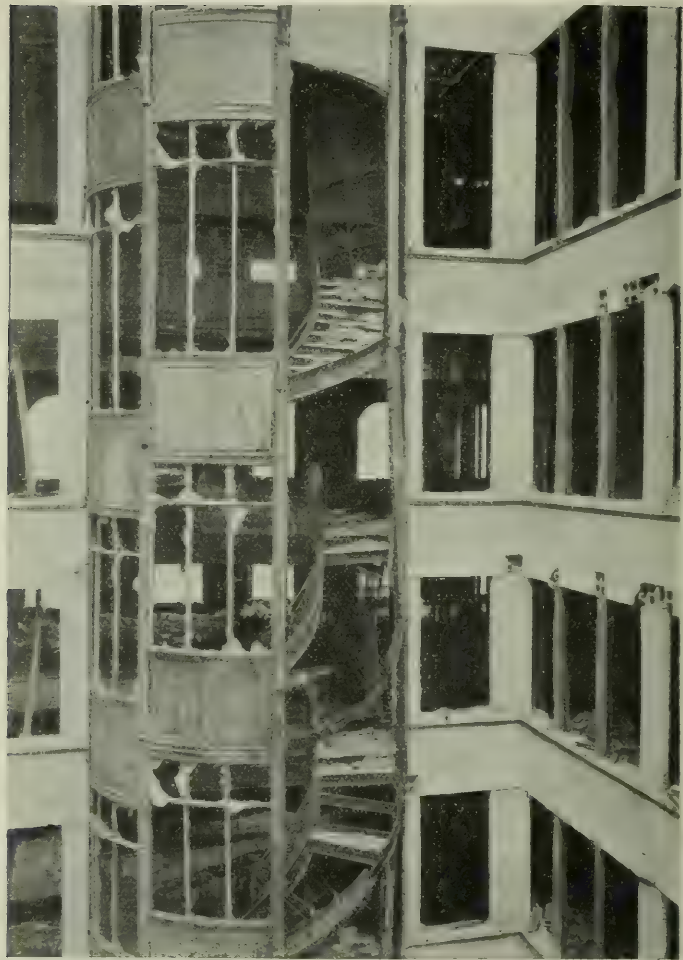


FIG. 58.—Enclosed Stairway, Merchants' Exchange Building, San Francisco. Note Failure of Cast Iron Horses and Marble Treads ; also Plain Glass Exterior Exposure ; and lack of Fire Wall isolating Stairway from Interior of Building.

are interested in the matter of fire prevention that shortly retroactive laws will make such contrivances criminal.

2. *Encased Stairways.*—Encased stairways are rarely protected by fire-walls or fire-barriers of a character

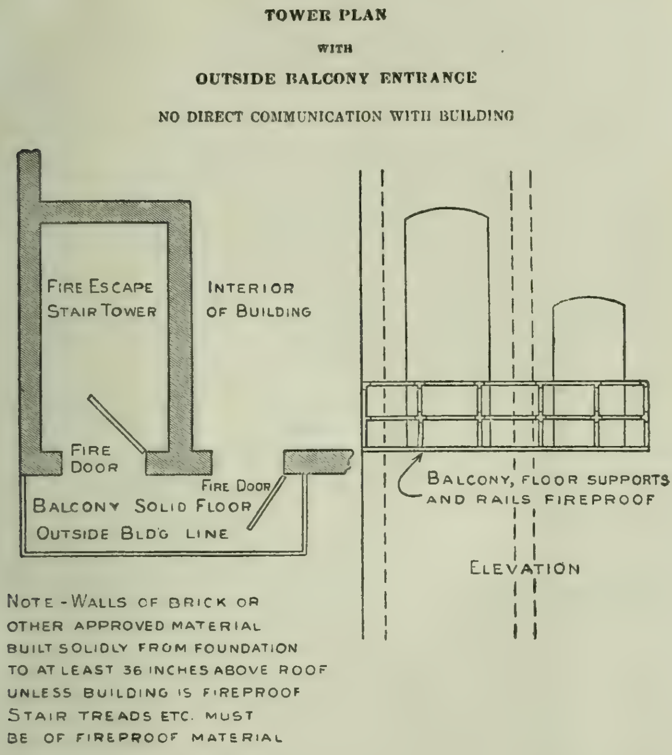


FIG. 59.—Fire Escape Stair Tower with Exterior Balcony Entrance.

to prevent the access of flames from the building, in which case the stairway, often surrounding the elevator shaft, becomes at once a stack serving as an excellent medium for allowing the fire to spread from floor to floor and entirely preventing the possibility of escape.

3. *Stairway Towers.*—It frequently happens that the

stairways are located in a special tower with plain glass exterior exposures and without a fire-barrier isolating it from the building proper, as illustrated in Fig. 58. A fire of any great intensity not only readily prevents its utility as an escape for the occu-

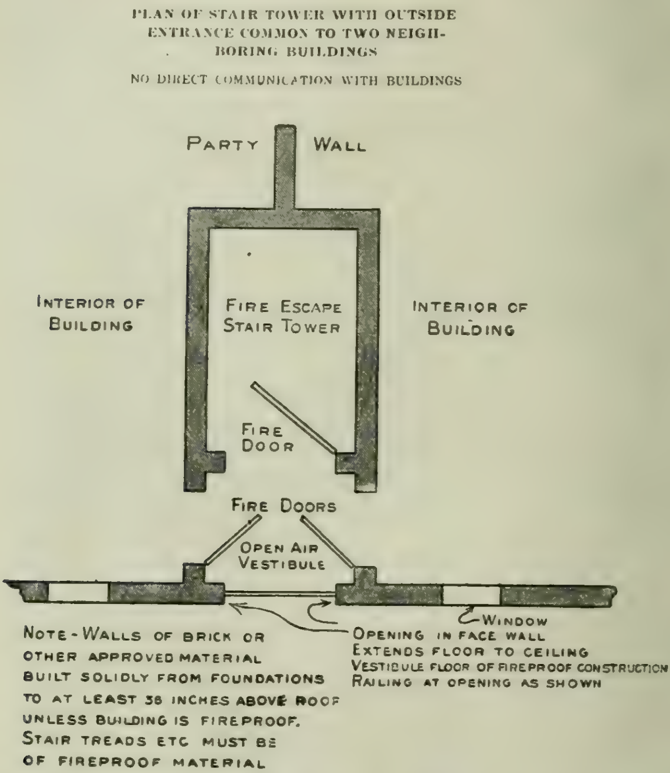


FIG. 60.—Fire Escape Stair Tower with Open-Air Vestibule Entrance.

pants of the building, but renders it an excellent passage for the fire throughout the building.

4. *Encased Fire-towers.*—The excessive number of lives lost in America in recent years has caused serious consideration and has led to the adoption of encased fire-towers, enclosed with fire-walls, to which access

can only be had from the exterior of the building. In order to enter this fire-tower it is necessary to pass out of the building, as shown in Fig. 59, on to a balcony and thence through a fire-door into this fire-escape, or one may pass into an open-air vestibule, as shown in Fig. 60, and from this into the fire-escape through the fire-door. It will readily be seen that this affords a much safer and more efficient form of fire-escape, having the highly desirable feature of preventing the access of fire and smoke to the tower and enabling people to pass into the tower with safety.

5. *Serviceability and Capacity of Exits.*—In the case of iron fire-escapes the length of time required for the occupants of the building to descend is so great as to render them wholly ineffective, especially so in such cases where the ladder is so steep as to make it necessary to descend backwards.

In the case of stairways, they are generally designed with sufficient capacity to provide exit for a single floor in a reasonably short space of time. Often the occupants of many other floors above descend to the stairway, which becomes over-congested and rendered practically useless. In the revision of many of the laws in America an attempt is now being made to regulate the number and size of the stairways in proportion to the number of the occupants of the building. In the preparation of the New York Building Code, some serious study has been made on the subject of exits, and the requirements have been so framed as to provide sufficient exits to allow the passage of all the occupants of a building within a reasonable space of time. But America must go still farther if it is to provide the degree of safety which every citizen has a right to demand, and laws must be so framed as to provide a number of isolated exits in the building in order to prevent congestion and arrange the openings in such a way that the occupants of all the floors cannot pass down the same stairway, but are diverted by the construction into a number of stairways. Fire walls should be provided in the building so that it would be possible in the event of fire on a given floor for the occupants to pass through fire-doors on the same floor and thus escape from the building in safety.

When the American people appreciate the fact that,

important as may be the conservation of their material resources, the conservation of human life is much more important, with this realisation will doubtless come the enactment of strict laws which will adequately provide for the safety of its people from fire.

Perhaps the most critical conditions in the matter of fire-escapes are to be found in schools, hospitals, theatres, and places of public assemblage. One only has to recall the Collingwood catastrophe, in which

Fig. 61.—Collingwood, Ohio, School House, showing Faulty Fire Escapes and general Flimsy Character of Structure.

several hundred children's lives were lost through lack of adequate fire-escapes and fire-drill. It has always seemed to the speaker that it was not reasonable to expect small children to exercise any degree of intelligence or calmness under the frenzy of a fire and to expect them to walk out of a burning building with order was unreasonable, and that we must provide such form of escape as can be used without thought on their part. Fig. 61 is a view of the schoolhouse above referred to, showing the flimsy character of the escape. While no steeper than usually provided, it

is, nevertheless, so steep that one must go down backwards with any degree of safety.

6. *Spiral Chutes.*—What should be provided in places of this kind are spiral chutes encased in fire towers similar to those to be found in the amusement resorts on the American continent, where one may fall in the chute and land safely several floors below without any effort. This provides an absolutely safe and speedy means of exit, and the fire-drill in a tower of this kind would be a matter of pleasure for the children, and such a drill would enable them to act promptly in the case of a fire and provide escape in perfect safety.

It is not sufficient argument for the fire-resistance of a material to say that the building was fireproof because the skeleton of a building stands, as often the value of the skeleton is only perhaps 15 per cent. of the total cost of the building (see Fig. 57).

We have in our buildings all over the world marble tiles, wainscotting, and various forms of expensive, easily destructible finish, and the loss of this ornamental part of a building represents a large percentage of the entire cost. A material like concrete could serve for this character of ornamentation, so that the destruction of the contents of the building would not involve the loss of its expensive ornamental features.

There seems no doubt but that concrete will play a very important *rôle* in the future of fireproof construction, and it was for this reason that the subject of fireproofing was selected for this address. The Concrete Institute of England and similar concrete organisations elsewhere have a very important responsibility and a very important duty before them. It is known that concrete is reasonably fireproof, but not much is known about its properties or the methods of construction from the view-point of developing buildings of the highest fire-resistance. It is a fact that in an investigation of the various concrete buildings erected in America, the owners of 26·6 per cent. of the buildings reported that they carried no insurance on the buildings themselves, but merely insured the contents, some even not the latter.

A structure of concrete when properly constructed

is a building of the highest fire-resistance ; unfortunately, there is a tendency to design the structural parts of a reinforced concrete building without providing any fire protection. It is just as necessary to provide fire protection for the concrete member of the structure as it is for a steel, a wooden, or a stone member. There is no doubt that different aggregates have various rates of expansion, which result in different degrees of fire-resistance.

It behoves the members of the concrete organizations not to stand on the superior excellence of concrete as a fireproofing material, but to study the question of fire-resisting properties and the methods of construction, so as intelligently to design structures in which the material shall be applied to the very best advantage. If conflagrations occur, and buildings of concrete, not properly constructed, are destroyed, it reacts against the merit of the material.

The destruction of building materials by fire is preventable, and, as previously pointed out, the fact that in America the loss is ten times greater than in Europe is no excuse why this country, with its years of experience and favourable conditions, should not exercise the same care to prevent the loss of 33 cents *per capita* of its property every year as America is trying to-day to prevent the loss of three dollars *per capita*, by the study of these problems, so that the whole world may be benefited.

The speaker could not address you on the subject of fireproofing without paying tribute to the admirable work which has been done in England, especially by the British Fire Prevention Committee. The effect of the work of this committee, which, as you know, is a work of love, has been felt especially in America and all over the world, and he is very glad to be able to testify to its merits and express his appreciation and thanks for the admirable work that this committee is doing, which deserves and needs support and co-operation. The chairman of the committee this evening related to the speaker some of the difficulties that the committee is working under, but he believes that, in an institute of this character, the study of these problems, the construction of buildings that have a very high fire-resistance, is something that should occupy your entire time.

America is constructing buildings of concrete, not from philanthropy, but because they are economical. In the first place buildings of reinforced concrete can in many cases be erected more cheaply than of slow-burning wood construction. In the second place, the insurance companies place a lower rate of insurance on such buildings than they do on the other. In the third place, the maintenance of the building is considerably less than in the case of wood or steel, so that the owner of such a building is not actuated by philanthropy, or a desire to help the cause, but he is governed by a dollar and cents proposition, and that is why so many buildings are being erected of reinforced concrete to-day, and it is a blessing to the country that such is the condition.

Unfortunately, the knowledge of the use of concrete is not definite, and there are many buildings erected which are very flimsy, and some day we may have occasion to regret their erection ; this makes it all the more important to study the subject frankly, admit the few weaknesses, and try to educate people to proper use of concrete both as a structural material and as a means of fireproofing.

In this address the speaker has given you matters of interest and thought. It is a matter in which he is particularly interested, and hopes to see the Concrete Institute join in the study of fire-resistance of concrete, because he thinks that is one of the most important phases of the study that needs attention at the present time. He is very glad to be with you and once more meet the members of this Institute. He stated two years ago that the National Association of Cement Users have a warm regard and high admiration for the work which you are doing, and he certainly brought to you the friendly co-operation and greeting of the American Association. He hopes it may be their good fortune to greet the members of this Institute, and that there shall always be between the two institutes friendly co-operation in the advancement of the proper use of this material.

DISCUSSION.

Mr. EDWIN O. SACHS, F.R.S.Ed. (Vice-President Concrete Institute) :—Sir Henry Tanner has

suggested that I should propose a vote of thanks. It affords me the greatest pleasure to do so, and I think that I am echoing the feelings of all present in saying that we are extremely indebted to Mr. Humphrey for devoting one of the few evenings that he is spending in London at the present moment to be with us and to give us such a highly interesting "talk." We are also extremely indebted to him for bringing over such interesting slides, for the selection presented was eminently interesting and instructive. They could not have been better thought out and brought together if an enormous amount of time had been spent on them. (Applause.)

Mr. Humphrey, at the commencement of his remarks, had mentioned the misnomer, "fireproof." The word "fireproof" has certainly been a most abominable misnomer, and to my mind it has done more to injure the progress of true fire prevention than anything else. It was a bugbear to that famous fireman Sir Eyre Massey Shaw, as far back as 1872, when he wrote scathingly about it in the public press, and I am afraid whatever has been done since to mitigate the use of that horrible word, it is yet all too fashionable, although its fashion is fortunately decreasing in certain degrees. In the United States, I know, there has also been much talk about the use of that particular word "fireproof," and I hope there will be substituted for it some day the more suitable word "fire-resisting," which is the word that is gradually finding favour in the British Empire.

The story illustrated in the lantern slides goes very far to show that the use of hard terra-cotta slabs or "tiles" is not to be recommended in fire-resisting construction. In fact, terra-cotta, whether it be tile or semi-porous terra-cotta, as now often found on the market, is certainly out of place where true fire-resistance is wanted. Nevertheless, you must always recollect that terra-cotta porous solid slabs and bricks could be safely used for light partition work and the like where only temporary protection is to be afforded in dwelling-houses and other domestic structures.

This method of discriminating between different degrees of fire-resistance makes me suggest that we

should adopt more universally classification between the different fire-resistants. We would require for a fully protected building far more than for one intended to afford partial protection, and, again, more than in one of "temporary resistance." Thus, while terra-cotta is useful for affording protection in domestic buildings and the like, and certainly formed a far better partition than the old-fashioned stud partition, it is of little use for the more dangerous class of buildings. The experience of actual fires in Europe and in the United States has gone to show this through the thorough investigations that have been made by Professor Woolson, of New York, by the Chicago Laboratories of the American Underwriters, and also by the British Fire Prevention Committee, to which Mr. Humphrey had referred.

Taken all in all, there is, I think, no doubt that if you weigh up questions of economy, practice, utility, and so on, a properly designed and properly constituted concrete will afford the most practical fire-resistance that can be got at the present day. And it would certainly be most welcome if among the subjects that the Concrete Institute took up, were a serious inquiry into certain phases of the fire-resistance of concrete which has not yet been fully entered into.

Mr. Humphrey said, however, and rightly said, that even concrete structural features require fireproofing. A reinforced concrete beam, with its metalwork partially protected with half an inch or an inch of concrete, is not a fire-resisting structural feature of any very great moment. Experiment and experience have both shown that for a practical beam of anything over 10 feet span, at least 2 inches of protective concrete, of proper aggregate, are required to protect the steel members. Should this not be possible, or practicable to obtain, or should in very large beams only 2 inches be given, then we must think of protecting that actual beam with another fire-resisting curtain or coating. Whether that coating be in the form of a plastic material, an asbestos plaster, or what I believe is being used at the present moment in the United States, a kind of pumice covering or cinder covering, no matter, but some kind of covering is certainly required for these very large reinforced

concrete girders, which show all too little protection at the moment to their metal members. Where the fashion has come from of not protecting the metal sufficiently I do not quite know, but I am afraid it comes, to a certain extent, from France and Belgium.

Only recently abroad I was looking over some very large concrete warehouses, where the concrete covering of the metal rods was chipped off in places, and it was scarcely half an inch thick, whilst in the panels you could literally, with the naked eye in the sharp sunlight, see each row of reinforcing material, and on being given permission to work at it a little with my penknife, I found that in these great buildings the protective covering was little more than a wash, it was somewhere between one-eighth and a quarter-inch. And this was in some of the newest, largest, and most extensive warehouses of the Continent.

As to the general features of fire protection in the United States, as compared with those in England, I think we have one very great advantage in this metropolis. We limit the cubic extent of our buildings, and, until recently, this was most strictly enforced. Now, with the tendency to build large stores and larger workshops, powers have been obtained through Parliament to extend those limits to a certain extent, and they are being so extended in many instances. A note of warning should here be sounded that the limits should not be extended too liberally.

The other great safeguard in London is certainly our height limit, and the fact that in our new high buildings the two floors and the roof have to be of fire-resisting construction.

Then, our other great safeguard is the splendid way in which the regulations as to party walls have been perfectly enforced ever since 1853. On top of these structural safeguards, we have one other safeguard which plays an important part. I do believe that we pay more attention to the safety of the life of the human being in this country than perhaps in any other country, including the United States. Life counts for more. With this provision for the safeguarding of life, we have received many regulations specifically intended, in the first instance, to save life, like the

provision of exits, staircases, and so on, and these all make towards better building construction as a whole.

In those four points I think we have a certain advantage over your great continent, and it is to be hoped that some of these points, which I know Mr. Humphrey has been studying in England and on the Continent, will be embodied in that great Building Act in New York which is now being worked upon, and drafts of certain portions of which the British Fire Prevention Committee and myself were honoured with for our observations a short time ago.

We have to thank the United States, however, for a great many things in the development of our building construction of late years. I think we have to thank them largely for a number of the better constructed floors that we have got over from the United States, quite a number of doors, and also for the more general use of wire glazing.

I would ask you, gentlemen, to accord our friend Mr. Humphrey our very best thanks for coming over and speaking to us in such a very delightful and interesting manner. (Applause.)

Mr. E. FIANDER ETCHELLS, F. Phys. Soc., M.C.I. (Council):—Mr. President and Gentlemen, I am pleased again to meet Mr. Humphrey after the interval of absence. I am also gratified by and interested in the lecture this evening. The meeting has been described as an irregular one, but it has been very interesting all the same.

With regard to the low loss of life in London, I think it is largely due to the provision of suitable means of escape, quite apart from the question of the construction of the building, and I have generally found that the loss of life has been due to the contents of the building—for instance, the Clapham Junction fire, and also the one last night in the Walworth Road. No matter how fireproof a building may be, the building owners (of course, for the best of reasons) cram as much goods into the shop as possible, so that the passages are only 2 or 3 feet wide. Take, for example, the ordinary newspaper shop, such as that in which the fire occurred last night, or the Clapham Junction fire. The position of affairs is such that, when one lot of goods takes fire, it immediately spreads

to the next lot. The question of getting fire protection for the contents of the building is so intimately connected with the question of rental values, the desirability of getting the most out of any given premises, that absolute fire protection is, I fear, almost impossible.

With regard to the question of "fire-resistance," as a term, instead of "fireproof," it might be pointed out that, in all recent legislation, fire-resistance is spoken of, and not fireproofing. It is generally recognised now that fire-resistance itself is merely a relative term, and you have only to get a high enough temperature and any material will melt. The highest temperature commonly obtained is about 4,000° C. in the electric arc. There are very few materials would stand that; but we need not go to high temperatures to get danger. Take ordinary iron or steel, at about 700° F., a temperature which is not much above the lowest visible heat. At that temperature steel loses about 30 per cent. of its strength. Immediately after that there is a very great loss of strength, and it is there that the danger occurs. Suppose a building be designed with the safety factor of 4, the calculated working stress being, therefore, one-fourth of the ultimate. The secondary stresses, which may not appear in the calculation at all, may be as high as 100 per cent. of the nominal working stress. You have, therefore, the actual stress equal to about half the ultimate, and then as soon as we mount to the increased temperature, the ultimate strength having been reduced by half, you have got disaster at once, and the building down upon the ground.

With regard to some of the illustrations this evening, I am very pleased to notice a great number of them where the pillars had failed with an absolutely central load. There have been many conjectures as to what extent in buildings the theoretical assumption of central loading would approach the truth, but we have had quite a number of instances of central loading, and that should give us all the greater confidence in dealing with our calculations.

Another noticeable feature was the improved strength of wired glazing, another instance of the advantages of reinforcement, for it is nothing else but reinforced glass.

Another feature noticeable in the illustrations was the superior advantage of the solid casing against the hollow tiling, and I am of opinion that part of the expansion in the hollow tiles is not only due to the expansion of air in the casing, or behind the tile, but is also due to the increased longitudinal expansion of the tile itself. As the length is limited from the ceiling to the floor, and as the tiles must expand in length, they bulge out just as railway lines have been known to do in hot weather.

Moreover, the solid tile has a better chance of being more uniformly heated. In the case of the hollow tile, there is probably a greater difference of temperature between the surface in contact with the flame and the surface in contact with the steel. This would cause a relatively greater camber or bulging of the outer face.

After seeing the illustrations, I am rather satisfied that we have in this country certain limitations as to the floor area and cubic extent. It does not follow, however, that the limitations should inflict great hardship on building owners, for there is practically no limit to the cubic extent of warehouses that may be erected and still comply with the regulations, provided that proper double iron doors and party division walls and floors are constructed in accordance with the Amended Acts.

It must be acknowledged that the smaller percentage of loss through fire in Great Britain does not necessarily indicate any greater constructive skill on our part. The lesser loss is a consequence of the greater value which we place on any human life, irrespective of nationality, and it is also a consequence of our system of land tenure, whereby the buildings become the property of the freeholder upon the expiry of the tenant's lease. The freeholder naturally insists upon permanent forms of fire-resisting construction.

In conclusion, I would like to ask a question of Mr. Humphrey. Mr. Sachs has told us that he considers 2 inches of protection the minimum for reinforced concrete. Mr. Sachs's experience has been largely in England and various parts of the Continent. Mr. Humphrey's experience has been gained in America. I would like to inquire what is his personal

opinion, as to what would be a good amount of cover or protection in the case of pillars, beams, and slabs respectively?

Finally, gentlemen, with regard to the vote of thanks, I think you all know, and I am sure Mr. Humphrey knows, that I most heartily second that vote with the greatest possible pleasure. (Applause.)

Mr. William G. Kirkaldy, Assoc.M.Inst.C.E., M.C.I (Council):—I should like to thank the author very much for the very interesting address he has given. It is a very great pleasure to see Mr. Humphrey over again in this country. I had the great pleasure of meeting him some time back and comparing notes together. I have been very interested in the slides he has shown. It has been very striking to see the effect of the fire on terra-cotta tiles. I thought previously that terra-cotta would make a very fair protection, but evidently that is not so, seeing so many columns very bulged. Incidentally I might mention they are very pretty, the symmetrical shape they took, bulging in so many places; they are very symmetrical. But I think terra-cotta should be avoided after so many cases as we have seen on the screen to-night, and that concrete is a far more promising thing.

I thank Mr. Humphrey for his address.

Mr. E. P. Wells, J.P., M.C.I. (Treasurer) (Council):—Mr. President, I am personally very much obliged indeed for the most interesting address that Mr. Humphrey has given us to-night, and there is one thing that I must congratulate him upon and it is this, that he has absolutely convinced me of the wisdom of what the London County Council have done in passing the 1909 Act, with this difference, that the Council, in certain stringent provisions they laid down in that Act, are not stringent enough. Now Mr. Humphrey has proved that, especially in column construction and the encasing of the same with fire-resisting materials, if you want to absolutely protect a steel stanchion from danger in case of fire it must be thoroughly encased in concrete. It ought, in my opinion, to be covered with a minimum thickness of 3 inches, and that in no case should any casing of what is known

as "plaster partition" be permitted; that it should in all cases be concrete, or, failing concrete, then brickwork set in cement. That is proved by the illustrations he has given, showing the effect of fire on steel stanchions, especially where they have been cased with tiles. Of course we know perfectly well that where concrete is filled in between the tiles and the body of the stanchion, in 99 cases out of 100 it is of a very inferior nature, but in the casing of stanchions, to make them absolutely fire-resisting, or as near fire-resisting as it is possible to do, the concrete ought to be of a very much richer nature than is generally used; the aggregate should be of a very fine description, not larger than about half an inch. Since the passing of the 1909 Act, I have seen stanchions encased with an aggregate made from broken brick and other similar materials, which had been passed through a 2-inch ring and without any sand. Now, in a case of this kind—and it is very common—it becomes an absolute physical impossibility with a concrete of such a nature to make it fire-resisting, because it is extremely porous. Such being the case, it follows that heat readily finds its way on to the metal. This applies not only to stanchions, but also in the casing of steel beams.

If it is necessary to get a concrete of a good fire-resisting nature, it is absolutely essential that a fine aggregate should be used. A large aggregate that would fly and sprawl will, when crushed to anything below half an inch, make a good fire-resisting concrete, and will not in any way fly.

To show how easy it is to court disaster even with a very carefully worded Act of Parliament, I have seen cases where wood firring has been put underneath steel joists so as to regulate the distance between the surface of the steel and the shuttering, and this has been allowed to remain in after the joist or girder has been surrounded with concrete. Now should a fire take place in a building where this wood firring has been allowed to remain in, one knows perfectly well that it would take a very short time, if the girder were subjected to great heat, before it would collapse.

There is another point that I was very pleased to see taken up by Mr. Humphrey, and one which I have

adopted for years past where it has been found necessary to use cast-iron columns in combination with reinforced concrete construction, and that is to fill the columns with concrete. Wherever possible, I always, in addition to the concrete, put in some steel reinforcing in the shape of rods. It not only strengthens the concrete, but it binds the same together if the column be not filled at one operation. I am very pleased to see Mr. Humphrey has so fully confirmed what I have done, and that is by proving by one of the slides that where a fire has occurred in a building where cast-iron columns have been filled with concrete, that the concrete core has carried the whole of the load even when the cast-iron has been seriously damaged.

The time, Mr. President, is now getting late, and I have no doubt that others will wish to say a few words, but before I sit down I have again to thank Mr. Humphrey for his most interesting lecture this evening. (Applause.)

THE CHAIRMAN (SIR HENRY TANNER): I will now put the vote of thanks which has been moved by Mr. Sachs and seconded by Mr. Etchells, and in doing so I should like to express my indebtedness to Mr. Humphrey for the very interesting observations that he has made, and also for the thoughts that he has raised. These slides, which he has shown on the screen, have been most instructive and far more impressive than anything any one could tell us as to the way fire has treated these different structures. I agree also with what has been said about tile casing. I never did like tile casings, and I have never used them, and the results of these fires have shown how very little they are to be relied upon. I have great pleasure in putting this vote of thanks, and I am sure you will pass it by acclamation. (Applause.)

MR. HUMPHREY:—Mr. President, the speaker does not wish to detain you long by unduly extending the remarks, but certain interesting points have been raised in the discussion. The subject of fireproofing is almost inexhaustible, on which one could talk for hours at a time. The speaker has endeavoured in the course of an hour to bring to your attention, in a way

that would probably leave an impression, some of the essential features of fireproofing from his point of view—the result of the experience which he has had.

Mr. Etchells brings out some points opening up a field of discussion which is most interesting. In England, as already stated, your Fire Prevention Committee has been engaged in studying the relative fire-resistance of materials ; in America, in Germany, and in Austria test houses have been made and small floors have been constructed, fires built under them, both with and without load, and tested. They have been most excellent in developing the relative fire-resistance of various structural materials and the comparative value of various forms of fireproofing. The city of New York had a requirement which compels new systems of fireproofing to undergo such a test. Almost every system tried failed on the first test, but in the test the patentee acquired a certain amount of wisdom and the second test was passed.

We must first know the relative fire-resistance of materials ; second, the relative fire-resistance of concrete with various aggregates ; but the most important thing that we do not know is the behaviour of a structure, as a whole, in a conflagration. If you can conceive of a warehouse of large extent, with contents of wall-paper or cotton, and consider that a fire occurs in the centre, an intense heat is generated—what happens to that structure? The parts immediately in proximity to the fire are expanded by the heat, which free expansion is resisted by the cooler masses that surround, and the result is that the great force exerted by reason of the expansion inevitably strips off the fire protection on the steel, or whatever the structure that carries that load.

Now, in the speaker's judgment, the most important thing in the building is the study of the expansion of the structure as a whole, and the value of taking a large floor area and breaking it up into 5,000 square feet or 100,000 square feet is that you reduce the amount of area that can be subjected to that expansion.

Mr. Etchells has asked what amount of protection is necessary in the case of a reinforced concrete column. It is frequently the practice to put 2 inches

of concrete on the outside of the reinforcement and $1\frac{1}{2}$ inches on girders and three quarters of an inch on slabs.

Now, that amount of insulation is just as valuable as 5 inches of concrete as fire protection. It depends entirely on how the steel in the structure is insulated. If in the course of construction there is a direct connection by metal that brings the steel in contact with the air, no amount of protective coating will protect that metal because the heat is transmitted through the metal, and its expansion strips the fire-proofing.

The speaker is of opinion that the best way to protect a column is to surround it with a metal fabric which will distribute the expansion of the concrete, and then, perhaps, a lesser thickness than 2 inches is desirable. But you cannot lay down a hard-and-fast rule as to how thick it should be. A building which contains merely office furniture does not require as much protection as a warehouse in which a large quantity of inflammable goods is stored, and you must gauge the amount of protective coating on the structural member by the character of the contents of the building. The American Joint Committee on Concrete and Reinforced Concrete have prescribed 2 inches on columns, $1\frac{1}{2}$ inches on beams and girders, and 1 inch to $\frac{3}{4}$ inch on slabs, and the speaker thinks that is quite sufficient.

The speaker's experience in studying the penetration of heat in fires and in the tests which were made by the Government of surfaces subjected to heat, is that in ordinary concrete and with temperatures that are well beyond what might be expected in an ordinary fire, the penetration of heat rarely exceeds three-quarters of an inch, and in most conditions it only penetrates perhaps half an inch.

This brings up a subject which has been frequently discussed, and that is the value of material like lime-stone as an aggregate in concrete. Now, it is a fact that if you keep the limestone aggregate away from the surface and you have a protective coating of silicious mortar, the limestone is just as good a medium for a fire-protective coating as other material. It is infinitely better than granite or gravel. But if

the limestone is subjected to the direct action of the flames, it is decomposed by the driving off of carbonic acid gas, and if water comes in contact with that lime it hydrates and disintegrates.

We have a method of fireproofing which is being gradually developed in America, in which cinders are used as the aggregate of concrete. Of course, there are all sorts and conditions of cinders, and the definition of the word "cinder" itself is very elastic and ambiguous. But if you take cinders as meaning clinker, and not the ordinary sort of ashes from the furnace—that is, clean and free from sulphur—and mix that up with cement, you get a material of very high fire-resistance, and if that material is put round as a protecting feature for a column or a girder you get a covering of superior excellence.

Recently the speaker has inspected buildings in which, through the action of sea water and salt air, the embedded steel has been so corroded that there was only a brownish trace of perhaps what was originally a $\frac{3}{4}$-inch bar of steel. That is a serious problem which we must study. It is just as important as the fire-resistance of the concrete. A study of the structure reveals the fact that the contractor in placing the reinforcement used in a $\frac{1}{4}$-inch bar of steel, the end of which was exposed; corrosion started at that exposed end, and as soon as it struck the main reinforcement the corrosion or rusting commenced and caused a swelling, stripping off entirely the protective coating of $1\frac{1}{2}$ or 2 inches of concrete. It is a fact that the floor above is still standing, but fortunately for the structure, the beam was a very deep one of short span, and by reason of an arch action there was sufficient strength to carry the load.

There was another cause for the corrosion of the steel. The contractor used a gravel which consisted of a mixture of soft shale and limestone. These particles of material, having a very high absorption for water, came in contact with the steel and became excellent mediums for the conduct of moisture and of carbonic acid, which, therefore, resulted in the corrosion. That brings to mind that you must use as aggregate for concrete materials which have low absorption

—the harder and denser the aggregate, the better is the concrete.

The protection of the embedded metal with a reasonable thickness of concrete is desirable, but the speaker believes that the problem of keeping the contents of a building segregated in small units of very small floor area—of not more than 5,000 square feet—with properly protected fire-doors and fire-walls, is the main essential in a building. Where you have a conflagration, it does not matter how thick the protective covering is if you have an enormous flat surface subject to heat action, the expansion of that surface will undoubtedly strip the protective coating. The expansion in clay tile is not so much the expansion of the air, which is made possible by defects in the tile itself, but it is the fact that terra-cotta has a much greater expansion under heat than concrete, and that very thin web of perhaps three-quarters of an inch expands very rapidly, and the lower web expands less rapidly, and as a result of this intensified expansion the web simply drops off.

The speaker believes that the points raised by Mr. Sachs are being considered largely in America. We do lose a great many people by fire, and there is apparently a great carelessness, but you must bear in mind that we have a condition that is the outgrowth of a very young country. While England reckons her civilisation by thousands of years, America reckons hers by hundreds, and we have barely outgrown the frame houses of the pioneers who settled America, and it is the gradual elimination of these frame buildings, that are such a menace to our population, that is commanding our attention. The law is getting more strict, and it is in this study and this evolution that some of the good things that Mr. Sachs has stated have been evolved. We still have many bad things, and we have looked to Europe and to England for a great deal of help in the solution of this very important problem.

The meeting then terminated.

THE CONCRETE INSTITUTE

AN INSTITUTION FOR STRUCTURAL ENGINEERS, ARCHITECTS, ETC.

REINFORCED CONCRETE IN SOUTHERN NIGERIA.

By H. C. HUGGINS, M.Soc.E., M.C.I., District Engineer P.W.D., S. Nigeria, W. Africa.

ALTHOUGH reinforced concrete has been much dealt with during recent years, yet the writer does not think that the subject has been touched upon from a tropical point of view to much extent.

The following brief notes on some such work lately carried out by him in Southern Nigeria might not be without some practical interest.

CLIMATIC EFFECTS.

The climatic condition of the country, especially around the region of the Niger delta, is one of extreme humidity from June to November, whilst the earlier part of the year is excessively dry. Variation in volume due to such changes is not found to seriously affect a moderate concrete after setting has once taken place. Rich mixtures should be avoided as much as possible in a country of this nature, where there are periods of great heat followed by excessive dampness. Great care must be exercised that the intense heat of the sun does not cause the material to set too quickly. In order to keep the surfaces of reinforced concrete

slabs, girders, etc., moist, and protected from the sun's rays during the setting process, a 2 in. thick layer of sawdust evenly spread over them and watered twice a day has proved an excellent protection.

Reinforcing metal must be immersed in water or thoroughly damped before being embedded in the concrete if it has been exposed to the sun's heat for any length of time before being fixed—often an unavoidable occurrence—otherwise the portion around the reinforcement sets too quickly and internal stresses are set up.

It would, from a reinforced concrete point of view, be advantageous to reserve such work for the cooler months of the year. This, however, cannot always well be arranged for, especially in the case of bridge work, which has to be pushed on when the rivers are not in flood and the season hottest.

River Wall at Calabar.

A reinforced concrete river wall is shown on Plate I, built at Calabar. The object of the wall was to retain a considerable area of low-lying marshy ground along the river front, and to serve as a wharf for boats.

Owing to the soft nature of the soil it was decided that a mass concrete wall of suitable section would have been too heavy and costly for the purpose in view. An economical light reinforced wall of the design shown was, therefore, adopted, the total length of which was some 400 ft.

Preliminary borings proved that at a depth of 20 ft., rails 75 lb. per ft. run weight could be driven to a firm footing, and these were accordingly placed at 10-ft. intervals, allowing the wall to be built in sections of that length. The wall was 12 in. thick and 10 ft. high, with a base of 5 ft. forming a toe towards the river.

The whole of the foundation trench was carefully piled with timber, piling 2 ft. 6 in. apart, decked with 2-in. planking, and upon this the wall was built.

Although it might be considered that the friction of the wall along this base is sufficient to prevent slipping, yet the tendency to slide was further safeguarded

by the insertion of timber battens, 6 in. by 2 in. thick and 18 in. long, securely bolted to the decking in two rows, below the expanded metal and between the Khan bars (the system of reinforcement used), thus forming a key (fig. 1*a*).

The reinforcement consisted of Khan bars cut into suitable lengths, placed 2 ft. 6 in. apart, laid horizontally along the base portion and vertically to a height of 7 ft. in the wall itself.

Expanded metal of 3 in. mesh was then inserted along the entire length of both vertical and base portion of the wall, care being taken to fix the shear members of the bars through the meshes of the expanded metal so as to allow a true alignment. The sheets of expanded metal were joined together by wiring in the usual way. It will be observed that the wall has been strengthened at the corner and the expanded metal bent in a suitable manner.

The depth of water at low tide was 2 ft., and by forming a dam of clay-puddle around each section as the tide receded, and pumping out the water expeditiously, the fixing of the reinforcement and placing of the concrete was successfully carried out. In this way the wall was built up to its height in 10-ft. sections as the tides permitted. The concrete employed throughout was composed of 4 parts of river stone, 1 in. gauge, and 2 parts of clean sand to 1 part of Portland cement.

The ramming was done in layers of 4 in. thick, and was personally supervised by the writer; 9 in. by 3 in. timber sheet-piling was used at the back of the wall to form false work, as well as to keep the foundations clear of being fouled by soft soil. Timber shuttering of 2 in. thick planed boards was employed for the facework, and a clean, smooth surface was obtained. The exposed facework was treated with a cement wash of 3 : 1 to ensure a waterproof finish.

The question of a suitable method of fixing the weepholes was a matter of careful consideration. Cement-pipes 12 in. long with 3 in. external and $1\frac{3}{4}$ in. internal dimensions were cast in sand and cement, 3 : 1, for insertion between the meshes of the expanded metal (Fig. 4), 5 ft. apart in two rows.

The joists with the face and back of the wall were

grouted with cement mortar, thus the reinforcement was effectively protected against leakage of water and consequent oxidization.

The light nature of this reinforced wall did not permit of any surcharge, and it was important that the filling behind be carried some distance back at the same level of the wall. It was also stipulated that no building should be erected beyond the point where it was considered that the limiting line of rupture would occur.

The attention of the writer has been drawn to some criticism as to the stability of a wall of this type.[1] It was said that a reinforced wall being much lighter than that of a mass concrete wall of similar height and base, the resultant of pressure due to its weight and that of the earth behind it would be dangerously near the toe of the wall. The writer would point out, however, that as the centre of gravity of the reinforced wall is considerably nearer the inside of the figure than in the case of a mass concrete wall, consequently the line of pressure will be found to be consistent with safety. Plate I, Fig. 3, explains the position.

Bridges.

Several bridges of the type shown on Plate II. have been recently erected under the writer's supervision. The particular one described was built over one of the Niger tributaries some 180 miles up the river.

The bridge was originally planned in two spans of 20 ft. each with cast-iron screw pile supports in the centre. It was subsequently decided, however, that the volume of water which would accumulate in the rainy season necessitated the addition of an extra span, and as no other piles were available at the time, the concrete pier was built.

The stream spreads itself over very swampy ground on either bank, and clay-puddle dams had to be built before the foundation piles and abutments were put in. The screw piles were tested with a dead load of 10 tons each until the settlement was observed to be $\frac{1}{16}$ in., before the reinforced concrete girders were

[1] "The Engineer," August, 1909.

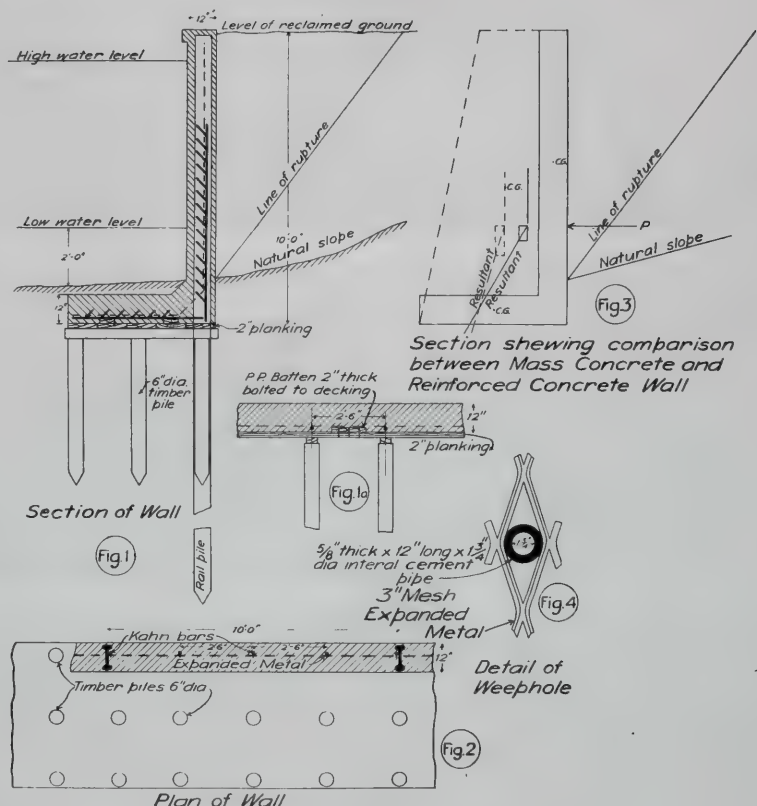


Plate I. River Wall at Calabar.

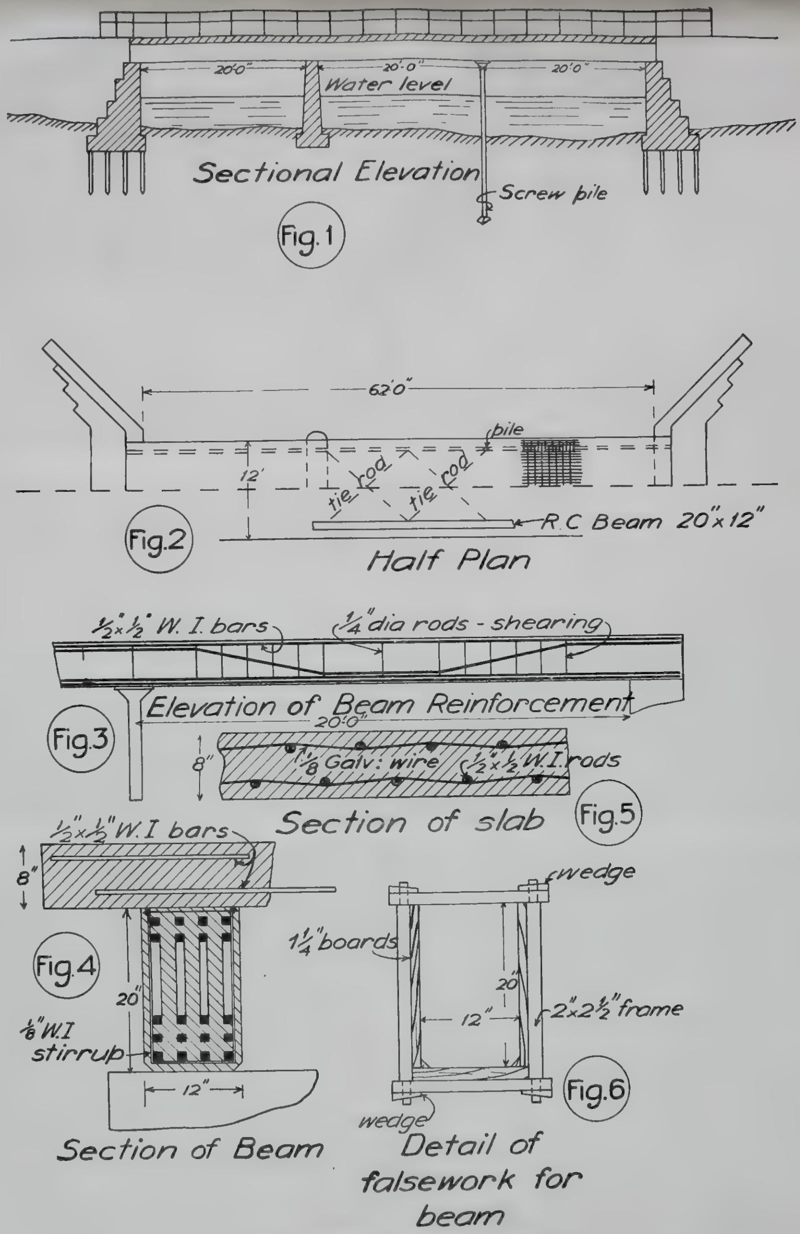


Plate II.—Bridge on a tributary of the Niger.

cast over them. Each girder, 20 in. by 12 in. section, was reinforced longitudinally by $\frac{1}{2}$ in. by $\frac{1}{2}$ in. iron bars placed in the manner shown in Figs. 3 and 4. Stirrups were provided at 3 ft. intervals, to which the bars were wired and reinforcement carried out as indicated. The centering was set to a camber of $\frac{3}{4}$ in. to allow for settlement, and the false work framed (Fig. 6) in a manner which allowed the sides to be removed ten days after moulding, leaving the bottoms a fortnight later.

The reinforced slab, 8 in. thick, which carries the roadway, was composed of $\frac{1}{2}$ in. by $\frac{1}{2}$ in. iron bars laid 8 in. apart, $1\frac{1}{2}$ in. from the underside, and interlaced with $\frac{1}{8}$ in. galvanized wire 4 in. apart. The projecting portion was reinforced in a similar manner $1\frac{1}{2}$ in. from the upper surface (Fig. 4).

The concrete in girders and slabs was composed of $3\frac{1}{2}$ parts of stone broken to a $\frac{3}{4}$-in. gauge, and $2\frac{1}{2}$ parts of sand to 1 part of Portland cement. All the reinforced concrete work is as far as possible monolithic, which ensures the structure being very solid.

Relative Advantages.

It might be asked whether reinforced concrete is a material to be economically applied in West Africa. In such an undeveloped country as this the engineer is faced with the question whether the local conditions lend themselves to that degree of economy which justifies its adoption. The saving in cost of material, and the facility with which iron rods and packages of cement in sealed tins can be transported over long distances of rough country are very apparent against the expense of heavy ironwork and the difficulties of transport it involves. But, on the other hand, it has to be borne in mind that native labour has not attained a very high standard of perfection. The engineer (who is certain to have many works to attend to at considerable distances apart) might with fair assurance feel that his iron girders and troughs can come to little harm while their erection is proceeding by a native staff in his absence. But reinforced concrete demands the constant personal supervision of a competent European foreman, and this supervision is

not always available at the moment the engineer would most need it, and it is a considerable item of expense when the question of cost of work is considered. The writer is of opinion that in West Africa, although the advantage in cost of material and transport is on the side of reinforced concrete, yet it behoves the engineer to look with special care into the question of supervision before rushing into reinforced concrete work too hastily.

TWENTY-SEVENTH ORDINARY GENERAL MEETING

THURSDAY, NOVEMBER 14, 1912

THE TWENTY-SEVENTH ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held in the Lecture Hall at Denison House, 296 Vauxhall Bridge Road, Victoria, S.W., on Thursday, November 14, 1912, at 7.30 p.m.,

MR. E. P. WELLS, J.P., the President, in the Chair.

THE PRESIDENT :—The first business that we have this evening is the election of new Members to the Concrete Institute. I shall not put each one to you separately, but will read their names over and assume they have been approved, unless I hear to the contrary.

1. MR. WALTER J. R. BARKER, Architect and Surveyor, Licentiate R.I.B.A., H.M. Office of Works, 16, Queen Anne's Gate, Westminster, S.W.

2. MR. GEORGE J. BERTINSHAW, General Manager, New Zealand Ferro-Concrete Structural Engineering Company, 92, Jorvois Quay, Wellington, N.Z.

3. MR. WILLIAM E. A. BROWN, A.R.I.B.A., 9, Regent Street, S.W.

4. MR. ROBERT CATHCART, Member of the Am. Soc. of Testg. Materials, Mem. Int. Assn. Testg. Materials, Mem. National Cement Users' Association, Madison Avenue, Cleveland, Ohio, U.S.A.

5. MR. ROBERT T. COOKE, Engineer, c/o British Reinforced Concrete Engineering Company, Ltd., 82, Victoria Street, S.W.

6. MR. J. D. CORMACK, Professor of Mechanical

Engineering, M.Inst.C.E., M.I.Mech.E., M.I.E.E., D.Sc. University College, London.

7. MR. J. PERCY DAY, Civil Engineer, Manager of the Eubœolith Patent Flooring Company, 3, Victoria Street, S.W.

8. MR. P. ION ELTON, A.R.I.B.A., P.A.S.I., Building Construction Surveyor, 113, Gloucester Road, South Kensington.

9. MR. JOHN W. GIBSON, Engineer, c/o Messrs. S. Pearson and Son, Ltd., Hull Joint Dock, Hull.

10. MR. A. W. GREEN, A.M.I.C.E. (Ireland), Manager, Samson Concrete Construction Company, Ltd., 71, 72, Broad Street Avenue.

11. MR. CHARLES M. GREGORY, Contractor of large Rly. Engineering Works in India, 16, Brunswick Place, Hove, Brighton.

12. MR. CHARLES A. DUNCAN, Engineer, Public Works Dept., Behar and Orissa, India.

13. MR. JAMES M. JARDINE, Clerk of Works, H.M. Office of Works, Edinburgh.

14. MR. A. BRYCE JOHNSTONE, Engineer, Port Victoria, Espirito, Santos, Brazil.

15. MR. WILLIAM RUSSELL KERR, Manager, Reid Bros. and Russell Proprietary, Ltd., 458–60, Flinders Street, Melbourne, Australia.

16. MR. W. H. LASCELLES, Contractor, 66, Victoria Street, S.W.

17. MR. WALTER J. H. LEVERTON, Licentiate R.I.B.A., M. Arch. Association, H.M. Office of Works, 22, Carlisle Place, S.W.

18. MR. S. G. LYTTLE, Assoc. Soc. Arch., Stud. Inst.C.E., P.W. Dept., S.M. Railway, Bijapur, India.

19. MR. GEORGE METSON, M.R.San.I., Licentiate R.I.B.A., H.M. Office of Works, Church Street, Islington, N.

20. MR. A. HEDLEY QUICK, A.M.Inst.C.E., A.M.I.Mech.E., A.M.Inst. Mun. and County Engineers, Engineers' Dept., London County Council, Spring Gardens, S.W.

21. MR. G. T. RITCHIE, A.M.I.C.E., B.Sc. (Birmingham Civil Engineering), Irrigation Dept., Cape Town, Transvaal.

22. MR. G. M. STONIER, Messrs. Richard Johnson Clapham and Morris, Manchester.

23. MR. J. EDGE TAYLOR, Designer in Reinforced Concrete, c/o Messrs. Trussed Concrete Steel Company, Ltd., Caxton House, S.W.

24. MR. WILFRID W. TONKIN, Licentiate R.I.B.A., Registered Architect, Transvaal Assoc. of Architects, P.W. Dept., Johannesburg, Transvaal.

25. MR. F. J. TREACHER, Manager, Steel Construction Company, Ltd., Malvern.

26. MR. H. A. TRISTRAM, Proprietor of Andrew Hawksley Patent Tread and Engineering Company, Columbia Works, Prescott Street, Poplar, E.

27. MR. HAMILTON H. TURNER, M. Quantity Surveyors' Association, 11, Dartmouth Street, Westminster, S.W.

28. MR. PERCY J. WALDRAM, Licentiate R.I.B.A., F.S.I., M.Arch.Assoc., M.Jun.Inst.Engineers, etc., 12, Buckingham Street, Charing Cross.

29. MR. F. VERNON WHARTON, Articled to Hon. A. G. Bell, P.W. Dept., Port of Spain, Trinidad.

The greater number of the members whose names I have given are resident in England, and a few of them abroad. There have also been admitted by the Council as Students the following :—

1. MR. T. H. ALDERTON, Engineering Cadet, Public Works Dept., Auckland, N.Z.

2. MR. PHILIP RICHARD DUNKLEY, Draughtsman, Trussed Concrete Steel Company, Ltd., Caxton House, Westminster, S.W.

3. MR. HARRY VINCENT WHITTAKER, Draughtsman, 125, Minories, E.

This, gentlemen, brings the number of members up to date to 899, students, 32, special subscribers, 7, giving a total of 938, so that we are getting very close to the thousand, which I hope we will attain very shortly. (Cheers.)

THE PRESIDENT (MR. E. WELLS, J.P.), then read his Address as follows :—

PRESIDENTIAL ADDRESS.

It affords me very much pleasure, in addressing you for the first time as President of the Concrete Institute, to congratulate you upon the various subjects that

have been taken up by the Committees during the past year, and also upon the satisfactory state of the Institute's membership, which, I am pleased to see, is gradually increasing, and it is the hope of the Council that before another two or three years are passed the membership will be doubled.

The Committees of the Institute have a great many subjects at the present time under consideration. The Science Committee, it will be recollected, drafted a Standard Notation for Calculations for Reinforced Concrete, which was subsequently adopted by the Joint Committee on Reinforced Concrete appointed by the Royal Institute of British Architects in their Second Report, and by the London County Council in their proposed Regulations covering the erection of buildings in reinforced concrete in London, while text-books which have been published in London since that date have also followed its recommendations. This, I think, will be felt as a great feather in the cap of this Institute.

You are all aware that the scope of the Institute has been enlarged—and not before it was wanted—to include structural engineering. The Science Committee has undertaken to compile a Standard Notation for Calculations in Structural Engineering generally. Further effort in the direction of standardisation is being made by the same Committee in drafting a standard specification for reinforced concrete work, which, at the present time, is very badly needed, and also a Report on the standardisation of attachments or joints in reinforced concrete. Other subjects of some importance are under investigation—viz., reinforced concrete piles, chemical tests for steel used in reinforced concrete, the adhesion of or friction between the concrete and the steel, and the effect of sewage, oils, and fats on concrete. In respect to the last named, it will have been seen that papers are to be given this Session on the same subject. These papers will be duly considered by the Committee in drafting their Report, and it will be in the recollection of many of you that a paper by Mr. Sydney H. Chambers was given in the 1910-11 Session on "The Effects of Sewage and Sewage Gases on Portland Cement Concrete," which, you may remember, was also very fully discussed at the time ; the full Report of the Meeting

is to be found in the Proceedings of that year. This Report will also be taken into due account by the Committee.

Other Committees of this Institute have also been very hard at work on other branches of the subject on which standardisation may be advantageously brought to bear ; and with regard to this, the Institute conducts a Joint Committee on Loads on Highway Bridges, upon which the Institution of Municipal and County Engineers and the Institution of Municipal Engineers have representatives. The Joint Committee is now engaged in drafting a Report, and no doubt when their work is finished it will prove of distinct service, not only to the Government but to the municipal authorities throughout the country.

The Tests Standing Committee have the following subjects under consideration, and you will note from the number of the subjects that a great amount of work will be entailed upon this Committee in gathering the information which in time will be presented to the members :—

1. The effect upon steel of the presence of sulphur in aggregates.
2. The grading of aggregates.
3. The expansion and deterioration of concrete due to changes of atmospheric temperature.
4. The effect of the use of sodium silicate on the surface of concrete as affecting reinforcing metal.
5. The erratic results obtained by the Vicat needle in ascertaining the initial set of cement.

The Reinforced Concrete Practice Standing Committee are investigating :—

1. Methods of treating the surface of concrete.
2. Cracks due to the expansion and contraction of reinforced concrete.

A special Investigation Sub-Committee has been formed to investigate failures and accidents in connection with reinforced concrete construction, and also the restrictions placed by the Local Government Board upon the granting of loans to local authorities for the purpose of undertaking work in that material.

The Committee which was appointed to consider the widened scope of the Concrete Institute, and whose Report in favour of the course of including within its purview the whole field of structural engineering was adopted by the Council, has not been wound up, but will continue to meet as an Improvements Committee.

I may as well state here that the Committees will be very pleased indeed to receive any matter of importance bearing on these subjects that any member may like to write to them, and I take this opportunity of saying that if any of you at the present time have anything in your minds bearing upon these matters to be dealt with, will you kindly communicate with the Secretary, and it will be laid before the Committees at their next Meetings.

It will be seen from the programme for next Session that the widening policy is already taking shape by the inclusion of a few papers on subjects not having immediate connection with concrete. The result has been that a greater number of General Meetings will be held this Session than last, and it is thought that a more interesting programme will be furnished. It may be mentioned that last Session only nine General Meetings were held, whereas for this year thirteen General Meetings and six Educational Lectures have been arranged. I may say the first one of the educational lectures started this week, and it was extremely well attended, I believe over 125 being present. It was decided, on the recommendation of the Improvements Committee, to have such a course of educational lectures annually, and also to hold an examination in structural engineering once a year to test the scientific or technical attainments of applicants for Studentship. The first examination will in all probability be held next year, and is in the right direction as regards increasing the status of members of the Institute because the qualifications for membership have been tightened up, and in due time it is probable an examination will be held for the admission of members, although it is hoped it will never be insisted upon as absolutely necessary to admit an engineer to membership, because there have been and no doubt will be engineers who for various reasons

will not or cannot submit themselves for examination, yet who are well qualified and would be worthy members of the Institute. At the present time the Institute is open to persons who are connected with the manufacture or commercial development of materials and methods of construction included in the field of structural engineering. Such members are of much value to the Institute, and I feel sure it would not be the wish of any one who has the interest of the Institute at heart to exclude such persons, although, if the policy of developing the structural engineering side is continued, it may be necessary to give such persons a special classification.

The Concrete Institute has now on the recommendation of its Committee the sub-title reading "An Institution for Structural Engineers, Architects, etc." The word "Architects" is included because they have to design structures from the engineering standpoint; but also they have to study the artistic side of construction, or the æsthetic treatment of structural materials. That is an aspect which the Concrete Institute has kept in mind and which it is desirable should continue to receive consideration; but I think it would be as well if the words "Institution of Structural Engineers" were added permanently to the main title of the Institute, though this is a matter that will probably come up later on. There are great possibilities in such a development, as there are evidently fine opportunities for such an Institution, and, considering that all the users of concrete must necessarily be connected with the theory and design of structures in some form or another, it is only a natural course to pursue on our part.

The work of the Institute is now growing very rapidly, and compared with what is being done by other institutions, the subscription is very small indeed. The Council, I think, have wisely adopted the decision to require an entrance fee when the membership reaches one thousand, which it is hoped will very soon be the case.

At the present time the Council have an insufficiency of funds to enable them to proceed in the direction of experimenting upon the subject of reinforced concrete, and until some method is adopted of

increasing the revenue this question of experimenting will have to be deferred. Mr. C. S. Meik informed me before the Meeting that the Institution of Civil Engineers have all the necessary plant for the testing of reinforced concrete slabs, and I think from what he said that they would be prepared to let anybody make the tests on the understanding that all data is communicated to the Institution and that it is done under their supervision. The only way that it seems possible to obtain the necessary funds will be to increase the subscription of the home members, but with regard to foreign members they might remain the same as at present. If this were done and the revenue doubled without any large increase of establishment charges, then the Council would be able to undertake experiments which would be for the good of all those interested in concrete and structural engineering.

I propose in this, my first Presidential Address, to deal almost wholly with the practical side of reinforced concrete construction, as I consider that the more often attention is called to this most important part of the work the better it is for all concerned, both for the engineer, the architect, the proprietor, and also the contractor.

With regard to the first and the principal constituent in concrete—namely, Portland cement—it is strange, at this present day, how many engineers and architects still adhere to the old specification of coarse grinding, consequently requiring aeration of the cement. It has been my lot only this week to come across a specification where it was stated the cement had to be spread on a floor for twenty-one days before being used. Those of us who are well acquainted with the present-day cement, and also its fine grinding, know how deleterious this is when great crushing strength is required. I think I have said, on more than one occasion at this Institute, that if cement is to be kept up to its full strength it is absolutely necessary that when it is received on the site of the works it should be stored in air-tight wooden bins : and if this is done cement may be kept for many years and be just as good after the lapse of time as it was when freshly made, whereas if the cement be

stored in sacks, and even a very small amount of moist air plays upon them, then the cement is rapidly hydrated and cakes in the sack. If, as is often the case, this cement be rubbed through a sieve, it becomes almost absolutely useless for purposes of concrete-making—by that I mean good concrete.

I have in my mind's eye a case of a contractor who bought cement in the month of October. The whole winter was a bad one, and he had very little opportunity of using the cement. It was stored in a shed through which the wind could blow freely, and he was rather astonished when the spring came and the cement was used that it would not set. He then wrote to the manufacturers, and when the matter was investigated the true cause of the mischief was found out.

I have myself on many occasions experimented with cement that has been so hydrated, and it is astonishing the enormous reduction in the strength, so much so that it becomes almost useless for making concrete.

Any of you who chooses to make the experiment can do so, and you will find that with the concrete made from an over-hydrated cement the amount of strength obtained will be very little indeed, and that its setting action will be so slow that it will practically take days before it shows much sign of hardening. The only use of such a cement is to mix with an over-clayed cement that is too quick setting ; by this means the setting action can be retarded.

Passing from cement, one is led on to the careful choice in all aggregates, the proper grading of the same, and also, what is of more importance, the seeing that everything is absolutely clean and the water pure.

I know it has been said that dirt is of some good in increasing the strength of cement concrete, but the only case that I can find where, over any period, a dirty aggregate increased the strength of the concrete was due to the fact that it had been mixed with a very over-clayed cement. It slowed down its setting action, and by that means did good ; but if the test had been carried over a lengthy period, it would have been proved how fallacious is the advantage to concrete of dirt in any form.

With regard to aggregates consisting of gravels that are dredged either from the river or from the

bed of the ocean, it is very seldom that the proper proportion of sand to coarse material is obtained. There is only one gravel that I know where one can see that the proportion is about correct, and that is obtained from the Spurn. In the ballast obtained from the Thames and along the East Coast there is at the present time a great excess of sand, and under any circumstances I would not in any way recommend that this aggregate should be used without separation of the larger particles from the finer and subsequent crushing of the coarse material.

The difference in the strength of concrete made with an excess of sand is very marked where the proportion of cement is not great; that is to say, 6 to 1 and 7 to 1 concretes with an excess of sand show very great falling off in strength, whereas with richer mixtures and an excess of sand, though there is a falling off in the early stages of hardening, after a few years the concrete will almost come up in strength to a concrete made in the correct proportions. Of course, it is well known that for all waterwork a large proportion of sand is required so as to get a perfectly dense mixture, but in no case must this be overdone.

In concrete for waterwork it is not necessary to add anything to make it watertight. If concrete be properly made it will be absolutely impervious to moisture, and if it be found necessary to reduce the labour some of these compounds of hydrated lime are, no doubt, of utility in decreasing porosity, but, at the same time, concrete so made is not improved in strength.

Before leaving the subject of aggregates I wish to call particular attention, as I have done here on more than one occasion, to the use of Fletton bricks for concrete. I have found lately that wherever Fletton bricks have been used disruption has taken place in the concrete, and I think this is due to the presence of lime in the bricks. Fletton bricks that are dangerous to use are those with purple markings, and great care should be exercised by all those who propose to use brick aggregate for concrete work to eliminate absolutely Fletton bricks in any form whatever. In this I am borne out by several who have been unfortunate enough to use the bricks, the result being that the concrete has failed.

I was called in only a few months ago to a special floor that had been put down for testing bowls, when it was found that about a month after the floor had been laid it was becoming uneven in places. On examination it was found that in every case where the floor had risen Fletton bricks in the aggregate were the cause of the mischief.

It is always advisable in the making of concrete that it should be got into the work as quickly as possible, especially in the summer : with low temperatures it is not of such great importance, as the cold slows the setting action and also its hardening. In frosty weather the drier the concrete and the more ramming, so long as there is no chance of displacing any of the reinforcing, the better for the concrete, as it will set very much more rapidly than if there is an excess of moisture.

With regard to reinforced work it is far better that the concrete should have a slight excess of moisture than a deficiency. Certain experiences that I have had lately have shown that where steel has been put into concrete that was too dry, the air and moisture had got through the porous concrete to the steel and caused rapid corrosion.

In one case the bottom layer of concrete had been put in and allowed to set, the steel was placed on the dry concrete, and other dry concrete was placed on top. When this work was broken up it was found that the rods in the concrete were quite loose, could be turned round by hand, and the adhesion between the two layers of concrete was anything but good. Now, had the concrete been made wet, there would have been no separation between the steel and the concrete, it would not have been possible to twist the steel rods round in the concrete, neither would moisture have passed through the concrete to the steel and caused oxydisation after the alkaline salts had disappeared by age owing to the presence of air and moisture.

Excess of moisture, as we all know, decreases the crushing strength of the concrete ; but at the same time in nearly all structures there is generally such an excess of concrete in the compression member, especially where T-headed beams are used, that it

is better to have the steel perfectly protected with a slightly weaker concrete than to have imperfect protection with a stronger concrete, because if imperfectly protected corrosion will be almost bound to take place, with consequent disruption of the concrete.

Excessive ramming in concrete is not at all necessary where it is made wet. It is far better to employ very light ramming and see that fine particles of the concrete are brought to the surface of the shuttering boards by means of steel slices or trowels. If this be done there will be very little danger of air finding its way through into the steel reinforcing, but a coarse aggregate first put in with an insufficiency of sand is almost always certain to have some porous parts through which the air and sulphur, especially in a London atmosphere, can attack the steel.

It may be well here to call attention to what I consider to be a most important point in reinforced concrete construction, namely, that as the concrete is being put into the work test-cubes should be made both for ascertaining the strength of the concrete *in situ* and exposed to the ordinary atmospheric conditions, and also to ascertain in the laboratory the strength of a series of cubes made at the same time and kept under laboratory conditions. One set of cubes should be kept on the works exposed to the varying atmospheric conditions, and the other at the laboratory at the normal temperature, say, of 60° Fahr.

Some years ago I made an experiment to see whether cold had any effect on concrete, and if so, to what extent. I found that in the month of December, when the cubes were taken from about 60° Fahr. and placed on a roof where the temperature fell to below freezing-point, a most alarming decrease took place in the crushing resistance of the concrete, and this remained so until such time as the weather became warmer, when the crushing resistance went up and was practically the same as shown by cubes made to the same gauging but kept under normal conditions.

This clearly shows that if a building is constructed in cold weather the crushing resistance of the concrete cubes kept on the works will be low, but if it be found that the other set of test-cubes, kept under laboratory

conditions, shows a rapid increase in the strength, then it is only fair to assume that the concrete that has been exposed to the cold air will, with favourable conditions, increase in strength and attain the same strength as the laboratory experiments.

The reason I am calling particular attention to this point is that if a building is constructed in the winter and the test loads are applied up to 50 per cent. in excess while the weather is cold, there may possibly be an excessive amount of deflection, owing to the fact that the strength of the concrete in compression is low, whereas if the experiment were held over until the warmer weather, when the compressive strength of the concrete was largely increased, then the deflection would be practically nothing—of course, assuming that the work in the first instance had been properly designed.

If the work is properly designed, and if the supervision has been strict and the work has been carried out according to the drawings, it is fair entirely to dispense with the testing of the structure so long as the experimental cubes show that the concrete has attained the strength required by the engineer or architect.

It is rather foolish to test a structure when one knows by experience that the crushing resistance, owing to the cold, is low. It would be far better to wait until the weather had become warmer and the concrete had parted with a lot of its moisture, when it would have become much harder. On the contrary, if it is found that the laboratory tests are low, say, for the sake of example, one month after being made, then I should strongly recommend testing of the structure to ascertain whether there were anything seriously at fault. Having those conditions of a low laboratory test and a much lower *in situ* test, yet the structure not exhibiting any serious deflection, then the work may be passed; but still, it is advisable in all cases to watch the crushing experiments, as upon these depends almost entirely the strength of the structure. A good crushing resistance means that the concrete is strong in tension, strong in adhesion, and strong in shear, and such being so, there is very little danger of the structure failing even if there is a deficiency of steel.

The testing of floors and other works is, as a rule, carried out on much too small a scale. Testing should be spread over an area that will at least take in always two sets of secondary beams as well as two spans of main beams completely. By this method of testing, the beams always have their full load and the adjoining beams become unloaded, which gives the most severe form of test, unless absolute continuous construction be carried out.

My experience has taught me that where concrete is good, that is to say, mixtures of 5 to 1 and richer, with the ordinary normal loading for which the structure was designed, unless most delicate instruments be used there will be no deflection recorded, whereas when weak concretes are used, namely, 6 to 1 and under, then the deflection at times becomes very great.

In all cases in making deflection tests, they should be made, not only at the centre of the span but also at the walls, as very often it is found that a large amount of the so-called deflection is due entirely to the squeezing of the brickwork, owing to the fact that the reaction has not been spread over a sufficient area of brickwork. In no case ought the load on the brickwork to exceed eight tons per square foot; by this means a good distribution is obtained and the brick walls are strengthened thereby.

In a great many works that I have seen where failures have taken place, the failures have been very largely attributable to shuttering and strutting. I have in mind cases of beams deflecting two or three inches after the concrete has been filled into the mould, this being due entirely to the strutting sinking into the soft ground underneath. In several cases this has caused what appeared like shear cracks at each abutment, though the work afterwards stood the test load satisfactorily. Still, such cracks made the beam look unsightly, and there could not have been the same adhesion between the concrete and steel, owing to this settlement, as if the boxes had remained perfectly true and level during the whole time the concrete was being put in and until the same were struck.

I know of one case of a failure taking place entirely owing to the strutting sinking into the ground, the sinking taking place over more than a week. The

concrete, therefore, never had the least chance of getting a fair adhesion to the steel, but was constantly being drawn away from it by this settlement of the strutting, so much so that when the strutting was removed the whole structure came down with a run.

It is always advisable, if there is any doubt at all about the ground, to have the latter tested beforehand, and it is far better to increase the sole-plates to double the size required, so as to prevent any possible chance of settlement, than to have an insufficient area with consequent settlement and trouble taking place.

Not only does the settlement cause a reverse camber of the beam, but it also gives a fall in the floors the wrong way, and it needs extra expense all round to make good such defective work.

All these are points that are easily obviated by the simple means of closely watching the work as it proceeds, and not allowing any concrete to be put in until the engineer or his representative is satisfied that the strutting is of such a nature that settlement is not likely to take place.

Strutting should always remain up as long as possible after the concrete has been placed in position ; in fact, if it were not for the exigencies of trade and also the rapidity with which building works of the present day have to be erected, I should personally like to see all strutting remain up for very much longer periods than is generally allowed, because the harder concrete can get before removal and any weight can get thrown upon it the better it is for the structure as a whole. Unfortunately, in the present day the question of expense has to be very largely considered, and to allow strutting to remain up as long as one would like it would increase in a great many cases the cost of the work, and I am afraid it would become almost prohibitive. Of course, in cold weather strutting must be left up for periods 50 per cent. longer than is allowed in the summer-time, and a great many of the failures in this country, and more especially in America, are mainly traceable to the removal of the shuttering and strutting at too early a period in the life of the concrete. The concrete at the time of striking was weak, but had an extra fortnight or

more been allowed for the hardening, then the works that have failed would no doubt have stood up.

Before finishing with concrete-making I would like to refer to water to be used therein. In this country, as a rule, water is almost invariably obtained from what is called a domestic source, namely, water supplied by large public companies who are extremely careful in what is sold to the public. Such being so, it is very rarely in England that one has to use water that does not come from the public supply ; but there are cases where it is advisable carefully to examine the same before it is used. There are some places where the water is highly charged with gypsum compounds, and such being the case, it behoves one to see that there is no likelihood of failure taking place owing to an excess of this compound.

In the South of France, in Algeria, and in a great many districts waters are highly charged with gypsum, and so bad is this in places that concrete is absolutely dissolved and disrupted in less than two or three years. Whenever there is any doubt as to the quality of the water to be employed an analysis should be made beforehand, and so what might lead to a disaster guarded against.

One of the great defects with regard to reinforced concrete is constantly raised by those who have not had much to do with the subject and often by those who are largely connected with it, namely, the difficulty of getting steelwork placed in the position designed by the engineer. It is a difficult matter always to get the work placed in the designed position, owing to the carelessness of the British workman, whose idea seems to be to get the material into position as quickly as possible, no matter whether it be right or wrong, and in a great many cases if he has an opportunity of leaving the steel out he will do so. The only way to get over this difficulty is not to allow any concrete to be filled or poured in until the steelwork had been passed by the engineer or his representative. If this be done there will be very little danger to be apprehended, because if the steel is in the correct position, if the concrete is proved to be as good as borne out by the *in situ* tests and by the laboratory tests, and if the strutting has not given

way, then one may fairly assume that the work has been well carried out and will sustain all the loads for which it is designed, and that there will be no deflection, or else of such a slight nature that it is not worth troubling about. If, however, the steel be badly placed, the concrete be poor, and the strutting has failed, then there is no knowing what is going to be the result.

In a great many years of practical experience I have come to this conclusion, that even if there is a large deficiency of steel in the structure both in tension and in compression, and the concrete is of an excellent quality, there is hardly any chance of failure taking place, but if the steel is up to and even in excess of the requirements asked for, and by any chance the concrete be poor, then if an excessive load be placed upon the structure, there is nothing to prevent it failing. As I have stated before, a rich concrete is strong in crushing, tension, adhesion, and shear, whereas with poor concrete exactly the reverse is the case.

A series of experiments that I carried out some years ago of some beams gave for thirty-three days' test a factor of safety of $5\frac{1}{4}$ to 1; in three years the factor was over 9 to 1. The whole of this was due entirely to a very good concrete which was absolutely homogeneous throughout, and when the beams broke they failed only at the centre, the only place where cracks developed. There was no sign of shear, and the diameters of the rods where the failure took place were, to all intents and purposes, the same diameters as when they were put in. These experiments, I think, simply show an enormous increase in the lever-arm, due to the rich concrete; in fact, in the case I now mention the lever-arm was practically the total depth from the axis of the tension members to the outside of the compression member of the beam; but even this will not account wholly for the enormous load that the beams carried, as the tests produced extraordinary stresses both in the steel and also in the concrete itself.

A great deal has been done by the London County Council School of Building in educating clerks of the works and others as to the method in which the prac-

tical part of reinforced concrete construction should be carried out. They ought to go a step lower and take in hand labourers who are connected with the carrying out of the work, because until such time as they themselves understand, to even a very slight extent, what is required of them, so long will they be careless in doing the work they have to do.

The foremen employed must be instructed to keep a sharp look-out on all their men, and not to allow laxity in any shape or form. If the men know that the foreman is up to all their so-called tricks of the trade, then they will take good care that the work is carried out in an efficient manner, but if by any chance the foreman is careless his workmen will be the same ; and it will, I think, very often be found that where anything serious takes place it is not only the men but the foremen and even the clerk of the works on the job who are answerable for this state of affairs.

Any foreman who persistently makes mistakes in the carrying out of the work, after the same have been pointed out to him, should be dismissed and not allowed to undertake any work of the kind in the future. It is only by making examples of men who do bad work that one can expect an improvement to take place in the industry in this country. Works executed abroad, as a rule, are carried out by men who seem to take a great interest in their work. Even the ordinary labourer knows what he has to do and does it, whereas in this country there are so many instances of scamping, not only in reinforced work but also in other branches of structural engineering, that it is only strict supervision in the past that practically made our work some of the best in the world, though I have very clear remembrances before me of seeing wooden rivets being used and other such things being done, and I daresay there are many in this room who have seen likewise. We do not hear of wood being put in for steel in reinforced concrete, that is to say, by the designer, but many accidents have proved that wood has been put in and has been the cause of the mischief.

A point that was investigated by the Science Committee some time ago was one which it is advisable,

I think, for me to call attention to, and that is, electrolysis. I have watched one work where this mischief occurred, and only about a couple of months ago I made a further examination and found that the mischief was still increasing. It is a moot point with some as to whether there is any electrolytic action or not, but personally I have very little doubt upon the subject, so that it behoves all designers and contractors to see that there is no possible chance of electric currents finding their way into the steel reinforcement, because, should they do so, I do not think there is any doubt whatever that it will mean the eventual disruption of the concrete. It only requires the exercise of care to put a stop to this and to be perfectly certain that all cables throughout the reinforced concrete work are properly insulated, and that there are no stray currents wandering about the work.

I think a great many of my hearers will agree with me in regard to the calculations of reinforced concrete work that a great deal too much mathematics has been imported into the subject and that common sense has had to take a back seat.

If we were dealing with two materials, both of which were absolutely constant—that is to say, the concrete constant within a month after it was made in strength as the steel is immediately after it is rolled—then it would be possible to go in for mathematical formulæ of a high order ; but where you have a material—*i.e.*, concrete—the strength of which, if all portions are good, is increasing day by day, and in some cases attaining a strength of three, four, or more times that which it was originally calculated for, how is it possible in these ways to formulate any formulæ which are even moderately correct ? It is far better to use more common sense and simplify or formulate empirical rules which you know are absolutely safe in their application. It is no good trying to extract the square root of two—it is useless. I have seen cases where the stresses have been worked out to five places of decimals, and it could all have been done by mental arithmetic, and the result would have been so close that it was really not worth while troubling about.

I see cases constantly where rods are put into work varied in diameter to 32nds of an inch.

That is not at all necessary. It wastes time on the work, and in a great many cases a wrong rod goes into the wrong place. It is far better to adhere in all cases to commercial sizes, never advancing beyond 16ths of an inch and if possible advancing only by $\frac{1}{8}$ths, as by that means the size on the rod is clear to the naked eye and does not require a caliper to be put upon it to find out whether it is $\frac{21}{32}$ or $\frac{22}{32}$ of an inch. Such reinforcements as these simply show how designers lack common sense and bring the work into disrepute. Exactly the same thing takes places with calculations submitted for approval. A mass of figures will be carried out into millions where the whole lot can be simplified by reduction into tens or hundreds, and the elimination of anything beyond two places of decimals. The simpler calculations are made, the less liability there is of errors creeping in, and if an error does creep in, then, it is much easier to discover ; but where a whole foolscap page of figures is used to arrive at a result, it means in a great many cases simply courting disaster, as well as being also a waste of time and expense with a view to possibly saving a pennyworth of steel.

I have always been a great enemy to the complicated calculations, as I do not think they are at all necessary. It only brings to mind the largest building that has ever been constructed in London. I am now speaking of as long ago as about five-and-twenty years. In an arch rib there was a deficiency in the centre of the span of, I think, half an inch in a large sectional area of steel. To make up this deficiency in compression a bar 2 in. by $\frac{1}{4}$ in. was riveted on, and this only for a length of two or three feet, thus making mathematics simply an absurdity, whereas no common-sense engineer would for the sake of half an inch in one hundred square inches ever think of doing anything so absurd.

The same applies to reinforced concrete. It is far better to work in all cases to commercial sizes of rods, even if there be a slight deficiency in sectional area, than to put in multiples of rods of all diameter so as to make up a given sectional area. This entails an enormous amount of work, not only upon the designer but also upon the foreman who has to take

charge of the work, and upon everybody connected therewith, and it is of no practical value whatever. Therefore I should like to see in all rules made for reinforced concrete that common sense should enter more largely into the formulæ that are given to the world, and not a mass of mathematics provided, which the authors know perfectly well are even then empirical, because one material is a constant and the other is an inconstant.

The Committees of the Concrete Institute have been seriously considering for a long time past the question of failures, and there is no doubt that if one could get at the whole facts of the cases with regard to failures they would be most instructive. As a rule, every work that fails has been kept in the background, for fear that the contractor or somebody in connection therewith would suffer either from the commercial point of view or the professional. It will be found, I think, as a rule, that the causes of failure are ones that can easily be allocated with the exercise of a little common sense and supervision. It is, as a rule, due to great carelessness on the part of foremen and workmen employed that the failures take place. Therefore it is advisable in all cases that the principal causes of failures should be known, in order that specifications may be made so rigid that there is little likelihood of these mishaps. It is the fear of failure that debars to a certain extent reinforced concrete from being used by many clients, and therefore it should be the object of all concerned with this matter, from a professional as well as from a commercial standpoint, to see that such care be exercised in the whole of the work, both as to designing, checking, and construction, that no one, for one single instant, should have any doubt but that reinforced concrete is for certain classes of work the best that can be employed.

It is no good, for instance, if a failure takes place where it can be fairly traced to a bad aggregate to keep the same a secret, because it means that others possibly in the same neighbourhood go on constructing work therewith and with the possible chance that failure will also occur, whereas had the fact of the failure been generally known there is not much likeli-

hood that a second disaster in the same locality would occur from the same cause. So that I make a confident appeal to all here to-night, and to all who may read the address, that wherever a failure in reinforced concrete takes place they will at once communicate with the Concrete Institute and let them have the facts of the case, not necessarily for publication but to enable the Institute to so word their suggested specification as to guard against a possible accident taking place in the future.

It is only by failure that we are enlightened. All through life it is the same way, and we only learn and remember our alphabet at school by making mistakes and being punished for such mistakes so that we understand. So it is in a minor degree with the subject I am speaking to you about to-night; the elucidation of a failure may be the means in the long run of saving an enormous amount of money.

I think I have trespassed on your time more than I intended, but I trust that the matter of this Address is one that we all have at heart; and if it is the means of causing work generally throughout the country to be carried out in a better manner than a lot has been done in the past, then it will be of some avail.

Mr. H. Percy Boulnois, M.Inst.C.E., Chairman of Council Royal Sanitary Institute, Vice-President Concrete Institute:—Gentlemen, I feel it a very great honour that I have been asked to propose a vote of thanks to our President for his address this evening. I have listened to that address with a great deal of pleasure, because I have been a President myself of a good number of associations, and when one approaches the question of one's address one is met by the initial difficulty of what can one talk about.

Now, I call the President's address a model one, because he has spoken to us of the subjects with which we have to deal. He has spoken to us of matters with which this great Institute is chiefly concerned. I think his epitome of the work that this Institute has done, and of the work that we hope to do in the future, is excellent. I must confess myself I am a little appalled when I see the work that is

before us as a member of the Council, and there is no doubt that this Institute is doing an enormous amount of good. I believe that this Institute has not only come to stay, but that, in a very short time, it will be a marked power in this country for engineering purposes.

The President has given us his address principally on what he calls the practical side of reinforced concrete construction, and I think you will all agree with me that he has thoroughly met that title. Unfortunately, the President's address cannot be criticized, or cannot be discussed, because there is enough material in his paper to keep us here for a week. He has given us so many heads and various points that each one of those, I think, would make a paper in itself which would be well worthy of discussion.

Take Portland cement, for instance ; he gives us a great many valuable hints with regard to Portland cement. I am old enough to remember when Portland cement was practically first used in this country, and when Mr. Grant, who was then one of the district engineers of the Metropolitan Board of Works, read a paper at the Institution of Civil Engineers which caused a great stir. I belong to one of the old school who still think it necessary to weather cement, and I am not alone in that. We are told by the President that we do more harm than good by weathering it, and that the present method of making cement, the grinding and the hydrating, and so on, that go on makes a cement that can be used immediately it comes from the kiln. In the old days we called it hot cement, which had to be cooled or aerated.

Then he deals with aggregates, a most interesting subject on which, of course, one could speak for a very long time. Then with regard to excess of moisture, it is perfectly true what he says, and excessive ramming, which is no doubt very often overdone ; the vigour of the British workman shows itself very often in the wrong direction.

Then his remarks on the effects of cold are exceedingly interesting. I have always suspected, though I have never carried out any experiments myself, that certainly frost had a very evil effect upon all classes of concrete.

Then with regard to his testing of floors; there, again, he gives us some valuable hints, which I am sure we shall all of us take to heart.

Then with regard to failures, he says they are very often due to shuttering and to strutting. That is, we know, very often the case. People are very often in a great hurry to remove their centering with very bad results, and his advice on that point is excellent.

Then with regard to the education of the clerks of works and of men; there I quite agree good work can be done by the London County Council if they will continue the education, not only of the clerks of works, but also of the men who are engaged specially on this reinforced concrete work. We all know in dealing with that class of work how absolutely important it is that every man should be doing his best in putting that concrete in, and should not shirk, otherwise disaster may follow. We can standardize materials, but, unfortunately, we cannot standardize men, and it is the personal element of the man that comes into our works so enormously, and the best design may be ruined by bad workmanship. That none of us can escape from. Then with regard to electrolysis, I think the fear of it has been rather overdone. I think it is evident that, with decent care, ordinary care, that could easily be prevented, and I agree with the President that it is a question whether it does affect reinforced concrete to the extent that people imagine.

Now, I also agree with him about the over-calculation business. Really, it is very often far too elaborate, and I absolutely and entirely endorse all that he says with regard to that. It really frightens one sometimes to go into the question of reinforced concrete because of the enormous calculations that have to be made, as he says, to the fifth place of decimals. It really brings reinforced concrete almost into discredit.

Now, last of all, he speaks of the importance of failures. There, as a man getting on in years, as a man who has been an engineer for perhaps fifty years, perhaps more, I entirely agree with him. I personally have learned more by my failures than I ever did by my successes, and young men should take that to heart and not be ashamed when they make a failure. Of course, we rub it into ourselves when we do make

a failure, and consequently we do not forget and we learn a great deal more by failure than we do by success. And in this class of work particularly with which this Institute deals we shall learn a great deal if members and others will let us know when a failure takes place, in order that we may make some investigations, and those investigations properly followed up will be of the greatest value to those who follow us in constructing work of that design.

The address, as I say, covers an enormous amount of ground, and I felt while the President was reading it that with a man as our figure-head for the year to come of that stamp as our President this Institution is in safe hands, and when he lays down his year of office we shall be exceedingly sorry to part with him. I beg to move a vote of thanks to the President for his address.

Mr. C. S. MEIK, M.Inst.C.E. (Vice-President of the Concrete Institute) :—Gentlemen, I have been asked to second the vote of thanks to our worthy President. Before doing so, I should like to express my hearty concurrence with all that he has said in his very lucid address, even to the extent of the cement. I also am quite at one with him in what he says about the workmen. Unless you get good workmen, you cannot do good work, more especially in reinforced concrete ; in fact, I would go to this extent and say, that for all reinforced concrete you ought either to train your own workmen or to be sure that you have not a man amongst them who has been accustomed to make concrete as it used to be made. The old-fashioned method of making concrete is, of course, quite out of place when you are dealing with material like reinforced concrete, and once get a labourer who has been used to the old style, you cannot get him to make good work in the new style.

I also quite endorse all that the President has said about the necessity of making test cubes when you are carrying out important works. Irrespective altogether of making laboratory experiments, cubes made as the work goes on are of great value afterwards, should anything happen to the work. If a failure takes place, for instance, during testing, by referring

to the cubes that you have made on that particular day, you can find out whether the failure is due to the cement, or to bad workmanship, which settles the point and relieves your mind to a great extent when you find that the cement is not at fault.

Now, as to the calculations, I quite agree with the President and Mr. Boulnois as to the necessity of simplifying calculations for this material as much as possible, and I would remark, what is the use of going to the fifth space of decimals, when you know, as I do from experience as the result of many tests, that the concrete itself varies as much as 100 per cent. in the same works, very often in the same day, due to different weather conditions or to different workmen? Intricate calculations in a case like that are quite unnecessary and useless.

Now, the President interpolated into his address a short statement about some tests that have been made by the Institution of Civil Engineers. I happen to be on the committee that made these tests, and I hope that the results will be published shortly. They have been delayed from unavoidable circumstances, but within the next few months I think they will be issued. The machine, if I may call it so, for making these tests is still available. A good deal of money has been spent over it, and the Institution of Civil Engineers have said that anybody wanting to make experiments the machine is at their service. The experimenter will, of course, have to make his slabs to suit the machine. It is not a toy machine, I may say, but one that will take in slabs that are in use every day, 15 ft. by 7 ft. 6 in., so that you get a reliable test of a slab that may be in actual use. The supervision of the tests will have to be carried out under the superintendence of some one appointed by the Institution of Civil Engineers.

Now, I beg formally to second the vote of thanks to the President for his very able address, and ask you to express your thanks in the usual manner.

MR. E. FIANDER ETCHELLS (F.Phys.Soc., M.Math.A., A.M.I.Mech.E., M.C.I.) was asked to support the vote of thanks, and said :—The President speaks of standard notation. The Institute may cer-

tainly congratulate itself on the fact that that notation has been adopted, both in schools and in books, and by official authorities, and by other technical institutions, to the exclusion of all counter-proposals, and if the same success follows the application of these principles to the formulæ of structural engineering generally, then this Institute will have done something to benefit the next generation. For ourselves, we have learned the principal formulæ that we are likely to require, and we will perhaps remember them in the old symbols, but there is another generation coming up, and engineering text-books will be very much simpler for them to follow. We do not know whether the extra time they will gain by finding the notation self-explanatory will be spent on sports, or on harder and more strenuous work in other directions. But that is for them to choose. We are giving them the time, they can dispose of the time how they think best.

As an instance of the number of books which are springing up in which the notation has been used, some that occur to my memory are Adams and Matthews, Faber and Bowie, Markham, Cubitt, Andrews, and one just written by Osborne, and there are many more in the press.

The President has also spoken about a committee which was to deal with the widening of the scope of this Institute, and he referred to it as the Improvements Committee. As chairman of that Improvements Committee, I would welcome any suggestions which the members have to make for the betterment of the Institute and the solidification of the profession. I would say to them : "Do not waste your grumbles on the desert air, but send them to me. I will lay them before the committee, and the committee will see what can be done to remedy the defects, if any."

The President has also spoken about the title. He said that the sub-title is "*An* Institution for Structural Engineers and Architects." I would like it to be more than that ; I would like it to be truer to the facts and make it "*The* Institution for Structural Engineers and Architects," because it is the Institution *par excellence* for them. There is no other institution in this country which combines architects and engineers as

one corporate body, though there may be in Austria and in Germany.

I also suggest that in doing that the David of the Concrete Institute is not in any way challenging the Goliath of the Institution of Civil Engineers, for the civil engineers have a far wider aim than structural engineering only ; they claim the whole of civil engineering, and structural engineering is just a branch and a part. The man who thinks that civil engineering is synonymous with structural engineering is a man who holds a view of civil engineering which was far too narrow for the Council of the Institution of Civil Engineers and far too narrow for the founders of that Institution, the doyen of engineering societies throughout the world. Perhaps it may be in a rather distant future that the Institution of Civil Engineers itself will become an Institution of *Engineers,* as it would at once if it included military engineers, who at present were only accepted as associates. I desire that the Institution of Civil Engineers should cover the whole profession and ultimately include the Royal Engineers. Then engineering would be a profession as deep, as profound, as wide, and as dignified as the Army and the so-called learned professions of the Law and the Church.

With regard to another point raised by our very practical President, the question of Fletton bricks, I utter a word of warning as to other bricks besides Flettons—namely, any bricks containing pyrites or other sulphur compounds. In the case of the Flettons the usual trouble is with a fossil known as the ammonite. A curly little thing it is, and it is mostly full of sulphur. It is frequently found in the Oxford clays, and it is a dangerous animal, even after it is dead. When it was alive its skeleton or shell was composed of calcic, calcareous, or silicious compounds, but long after its death the house that it had vacated has become filled with pyrites which have been deposited from percolating water. Frequently the original material of the fossil has been entirely removed. In organisms with calcareous skeletons the lime is readily dissolved by water containing carbonic acid. I have heard it said that brickmakers are to beware of clay containing ammonites. It is not the

ammonite which is the danger, it is the sulphur which fills his house after he is dead.

Many of the fossils are composed entirely of pyrites in the form of ferric sulphide, having the formula FeS_2, and this may lead to disruption of the concrete and consequential corrosion of the steel.

With regard to another point, we have been told that we must not discuss a presidential address. It is one of the rules, but if I could discuss the presidential address, I would say that the deflection varies inversely with the elastic modulus and the elastic modulus of concrete increases with its age. If the concrete is new, the elastic modulus is rather low and the deflection is relatively high. Deflection is proportional to stress and inversely proportional to elastic modulus.

The President has spoken about intricate calculations, and he has spoken about them being introduced in certain official documents. In the first draft of the regulations which was issued to the technical societies the formulæ were simple, but certain technical societies said : "Oh, no, we cannot have this ; this is empirical, this is approximate, this is inaccurate ; we want something that is exact and scientific" ; and so the building authority made them more scientific. But still the other side were not pleased then, and also when formulæ which were simple were given side by side with the formulæ which were complex the technical Press said : "Oh, strike out these simple ones ; they are not true ; they are not correct." I prefer simple formulæ for the practical purposes of design.

I suggest that this Institute might have a Formulæ Committee, which would discuss and arrange simple formulæ, which would be approximations to any official regulations or official reports which there may be. There is a Report of the R.I.B.A., but that Report has been made scientific because it was held that the function of the Committee was to set out the truth as near as they could, and it was the function of engineers engaged on the work to take such approximations as they considered necessary or safe. One cause of the non-dissemination of simpler methods is that some people think, This or that is their particular

patent method. They discovered it themselves. They are not going to tell anybody else how they do it.

Now, there are perhaps some hundreds of persons, all having what they call secret patent particular methods of their own discovery, but as soon as these are put into a standard form and notation it is found that they have nearly all the same method. In how many cases are approximations made with regard to the lever-arm of reinforced concrete tee-beams? The exact equations are rather lengthy, but there is a very simple rule of taking the distance from the centre of the tensile reinforcement to the centre of the area of the slab. This is only just about the same distance as taking the overall depth of the rib of the tee-beam, measured from the underside of the slab to the underside of the protective concrete or "cover." These two methods are very much quicker than the long formulæ. Very many designers who speak darkly about their short methods if they would only come out and say exactly what they have done would realize that they are all nursing the same secret, except where they may be nursing diverse errors.

In support of what has been said about the decimal places, I have had calculations submitted to me in which the thrust of coal in a large bunker showed so many tons and five places of decimals. With regard to the use of a larger unit, one of the great handicaps of the metric system has been the smallness of the units selected. The millimetre and the centimetre are too small for general use in buildings. If they would only use a decimetre it would be far better. I suggested that 100 lb. might be used as a unit. In 1878 the British Government did advise the use of the cental (which was 100 lb.), and years ago I introduced 1,000 lb., which I called milal (from *mille* = 1,000 and the suffix *al* = pertaining to) (analogous to *cent-al*).

Since then in America, *kip* has been used, a contraction of kilo-pound, or 1,000 lbs. In the first draft of the regulations stresses were given in thousands of pounds, but suggestions were made that we should not use these new units, but give pounds. The building authority wished the regulations to be widely understood, and they accepted the suggestion. I do not

think it is a good suggestion, but if the technical societies wish the change, the onus and the labour is on their hands.

With regard to the roof that has been mentioned in which there were about 100 sq. in. in the tension flange and they were 2 in. short, it is rather painful to realize that after they had put on this piece of 2 by $\frac{1}{4}$, they still had not got the requisite area, because they had not allowed deduction for the rivet-holes. The precisionists failed in precision.

The President had spoken of failures, and suggested that whenever a failure in reinforced concrete takes place the person should at once communicate with the Concrete Institute. I propose an amendment, and suggest that they should instanter communicate with the district surveyor, and when the building is shored up, they can then come round and tell the Concrete Institute how it happened. I would also like to reinforce what the President has said by pointing out that failures are not due to combining iron and steel, but are due to ignorance of mechanics, ignorance of chemistry, to the error of assuming the ends of a beam or pillar are fixed in theory when they are not in fact. I recently saw in the papers the case of the failure of a reinforced concrete mansion. There it was the mistake of cocksureness ; the occupants seemed to be holding a levee underneath the test load. Five persons were killed and ten others were frightfully injured.

I also suggest that reinforced concrete should not be judged solely by the failures which have happened. Automobile engineering was not judged solely by the accidents which happened in the early days, when the cars were built higher and they overturned on going round corners. Aviation is not judged solely by the failures of aeroplanes or dirigibles. They built stronger aeroplanes, and with new men they made other and longer flights. Therefore we should not judge reinforced concrete practice solely by the accidents which happened in its days of youthful indiscretions. It is a material which can be dealt with by the ordinary laws of mechanics, supplemented by common sense—and a deal of common sense to make up for our ignorance of mechanics.

Coming more particularly to the more personal part, those who had known the President longest knew that he did use short methods of calculation ; they also knew that he could guess nearer than many men could calculate. A lot of it may be intuition, because he has the constructive instinct, but he has some very short methods of calculations which are worthy of being followed. Then also he has had long experience in concrete work, for in 1878 he was building lighthouses, and some of those lighthouses are still standing, defying oceanic and titanic gales.

MR. BOULNOIS then put the motion, which was carried by acclamation.

THE PRESIDENT :—I have to thank you very sincerely for the kind words that you have said about my address, and some of the points that have been raised, not in the shape of discussion, I trust will be taken to heart by the various committees later on and possibly before this time next year, when I have another address to read before you, I may refer to some of these criticisms by our friend Mr. Fiander Etchells.

The Meeting then terminated.

TWENTY-EIGHTH ORDINARY GENERAL MEETING

THURSDAY, NOVEMBER 28, 1912

THE TWENTY-EIGHTH ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held in the Lecture Hall at Denison House, 296, Vauxhall Bridge Road, London, S.W., at 7.30 p.m., on Thursday, November 28, 1912.

MR. E. P. WELLS, J.P. (President) in the Chair.

THE PRESIDENT (Mr. E. P. WELLS, J.P.):—Gentlemen, the only business that we have before us this evening is a paper to be read by Mr. Theobald upon "Bills of Quantities for Reinforced Concrete." I will now call upon Mr. Theobald to read his paper.

MR. JOHN M. THEOBALD, F.S.I. (Member), then read his paper as follows :—

BILLS OF QUANTITIES FOR REINFORCED CONCRETE

When I think of the papers that I have listened to at the meetings of the Concrete Institute on various occasions—papers of the highest technical interest to the members of your profession—I feel that I owe you

an apology for venturing to read a paper the title of which concerns you only in the abstract, and not —may I say it?—in the concrete. In extenuation, however, I would mention that the reasons for my offence are twofold. In the first place, the title of the paper was supplied to me by our Secretary, and, secondly, because I feel very strongly that so revolutionary a suggestion should, in the first place, be submitted to the members of the Concrete Institute for their opinion before it is discussed—as it undoubtedly will be in the near future—at the headquarters of the members of my own profession.

When a criminal pleads guilty, I believe the sentence is usually less severe than if he persists in denying his crime; so that, if I am charged with holding a brief for the quantity surveyor, I at once admit the offence, but I shall endeavour to show that his employment will be advantageous to the interests of the client, of the architect, the reinforced concrete specialist, the contractor, and—anticipating an obvious comment—the defendant himself!

I trust it is unnecessary for me to say that, in reading this paper, I am making no reflection upon the quantities supplied by the specialists under the present system, either upon the score of inaccuracy or otherwise. Such a charge would, of course, be quite unjustified and unjustifiable; my criticism is solely directed against the system, and not against its exponents.

Far be it from me to say a word against clients—our clients particularly. There is no class of men for whom I have a greater respect and admiration, but, like every one else, they have their peculiarities—one of which is conservatism. The client who is about to erect a building goes, in the ordinary way, to an architect to prepare the plans, and then either he, or his architect with his permission, employs a surveyor to prepare the bills of quantities, who, when the final account is presented, can be cross-examined upon the items *ad nauseam*, and whose life can be made a burden to him until the matter is settled. This is what the client likes! This right of criticism gives him a sense of security and makes him feel he is getting value for his money (with which, from personal experience, I cordially agree!), and it is the absence of

this facility for cross-examination that makes some people fight shy of availing themselves of the many advantages of reinforced concrete. This may strike you as being very absurd and unreasonable as, no doubt, it is—but the feeling of insecurity is there, and any means by which it may be lessened or removed are surely well worth employment.

Lest you may think that this theory is an effort of my imagination, I may mention that, in my own experience, I know of two buildings in which steel construction was used in preference to reinforced concrete solely for this reason.

At the present time, when an architect decides to construct a building of reinforced concrete he sends a set of plans, sections, and elevations to one or possibly more firms of specialists, who then submit a scheme of construction under their respective systems, together with an approximate estimate of the cost. The firm whose tender is accepted by the architect then prepare their working drawings, which, with a bill of quantities (also supplied by them), are sent to the contractors, and the accepted tender is either incorporated by the quantity surveyor in the quantities sent to the general contractors or is the subject of a separate contract, as the case may be.

Reinforced concrete, from the point of view I am taking to-night—that of the quantity surveyor—has but recently emerged from a healthy infancy ; but, now that its employment is being adopted on all sides, there is a feeling, not confined to the members of my own profession, that the specialist contractor should receive the same treatment as the builder, and it is with the grounds for that opinion that I propose to deal this evening.

In advocating the claims of the quantity surveyor in connection with reinforced concrete, I am well aware that I shall be told that time does not admit of his employment, and that until the details are complete he would be unable to commence his work, and the delay thereby entailed might be considerable. I may say at once that I admit the objection, and my reply is that the client must wait. If the building were, let us say for argument's sake, a steel-frame building, the steelwork details would have to be prepared, and

I am sure that I should be libelling the members of the Concrete Institute if I were to suggest that they take longer to supply their details than do the steel manufacturers.

Of course, there may be cases in which rapidity of construction is everything. Under those circumstances, I say at once that the preparation of bills of quantities by a quantity surveyor is impracticable. He may still, however, be advantageously employed in the preparation of a schedule of prices and subsequent measurement. It has been my experience—and I think all architects and engineers will agree—that the average client's conviction that the world will cease to revolve upon its axis unless his particular building is erected in an utterly impossible time is not warranted. It is only natural that he should require the work completed with the least possible delay, and a visit to quantity surveyors' offices at, say, eight, nine, ten, or even eleven o'clock at night should convince him that they fully recognise the necessity for "hustling."

Under the present system the quantities issued by the concrete specialists, by their own showing, are prepared before the working details are complete, but granting the necessity (which I do not), I admit that they are in a better position to do their work under these conditions than would be the quantity surveyor, by reason of their employment of constants and formulæ of which he would have no knowledge. It must surely frequently happen, however, that in making the various details it is found necessary to alter the drawings from which the original quantities were prepared, and the latter are, consequently, inaccurate to that extent.

I believe that under the present regime their correctness is not guaranteed, which, assuming for sake of argument that the drawings from which the building is subsequently erected differ from those from which the quantities were prepared, would seem to press unduly hard upon the contractor. I say the contractor because I consider the risk in this case is more likely to be his than the building-owners', as the alterations would more probably tend to increase the cost of the building than to diminish it. If I am wrong in my statement or the deduction I have drawn from it, I

shall, of course, be corrected. It is obviously not a point upon which a quantity surveyor can have first-hand knowledge.

The forms of contract under which reinforced concrete construction is carried out are, as far as my own experience extends, four in number :—

1. The "lump-sum" contract, in which the contractor undertakes to erect the building for a stipulated amount—no mention being made of the method of dealing with any variations that may arise during the progress of the work.

   Anything in the nature of a "lump-sum" contract of this description is, in my opinion, most unsatisfactory. As, however, I am dealing more fully with this particular form of contract under the next heading, I will merely mention that, unless a surveyor be employed, the contractor's account for extras has apparently to be accepted—his original priced bill of quantities not being accessible, presumably, without his permission. This form of contract would not be entered into in the case of an ordinary building, and I fail to see why any exception should be made in favour of reinforced concrete.
2. The "lump-sum" contract in which the bills of quantities do not form part of the contract, but the contractor undertakes to deposit a copy of his priced bill of quantities, which, as regards prices only, is to form a basis for arriving at the value of any extra or omitted work.

   In a large reinforced concrete job upon which I was recently employed under this form of contract, there were various mistakes in the bills of quantities—both for and against the building-owner—with which I was, of course, precluded from dealing, and one of the parties to the contract—I emphatically decline to state which profited thereby.

I need hardly say that I am using this case solely to illustrate my point—the unfairness of the "lump-sum" contract—and not with a view to emphasising the possibility of errors in the quantities. Everybody makes mistakes, quantity surveyors among the number ; but in cases of error in the original quantities, the disability under which one or the other of the parties to this form of contract is placed is so obvious that I cannot understand why it is ever entered into. In a few cases, of course, there may be some reason for so doing, but speaking generally, I can find no argument in its favour.

3. The "lump-sum" contract, in which the bills of quantities form part of the contract.

   This form of contract has none of the disadvantages of the two previous examples. It is certainly fair to both employer and contractor, provided a competent surveyor is employed, but it relieves those responsible for the bills of quantities of all liability for their accuracy. If, however, as I said before, this liability is never accepted, the criticism, of course, has no point.

4. The "lump-sum" contract, in which the bills of quantities form a schedule only, and the entire building is remeasured.

   My only comment on this form of contract is that, unless under circumstances where the erection of the building in the shortest possible period is of vital importance, it seems needlessly extravagant. It is quite possible, however, that the cost of the initial and subsequent measurements may not exceed the alternative cost of the preparation of bills of quantities and measurement of variations. It is merely a question of fees, upon which wild horses will not induce me to touch !

If, however, I urge the employment of a fully qualified quantity surveyor for the preparation of quantities for reinforced concrete, I do so even more

emphatically when we arrive at the question of variations.

It is apparently not usual for the concrete specialists, who prepare the original quantities, to settle the extras and omissions at the completion of the contract. I hasten to add that I am speaking from my own experience only, and if I am wrong in my conclusion, I shall doubtless be corrected. If I am right, I can only congratulate them on avoiding a tedious, and often unpleasant, job. The measurement of variations —I am again speaking personally only—is an acquired taste even when dealing with one's own bill of quantities, but in reinforced concrete, unless under these circumstances, it is anathema.

Quantity surveyors, from bitter experience of variations, have learnt to "take off" with a wealth of detail which would probably surprise you if you were to take the trouble to wade through their dimensions—a fate to which I would not consign my worst enemy. You would find that, whereas to the uninitiated the description of the item itself is comprised in half a line of utterly unintelligible abbreviations, a further two or three lines are taken up by a description of the particular portion of the building in which the item occurs.

I remember on one occasion I endeavoured to describe to a friend of mine the precise nature of a quantity surveyor's business. I took a lot of trouble over the explanation because, for some inexplicable reason, he seemed interested, so I was encouraged to give him a description in detail, with which he appeared duly impressed. The impression, however, was hardly of the admiring character that I anticipated, as he merely remarked that it seemed to him quantity surveying was not so much a profession as a disease!

I have laboured this point, I fear, somewhat unduly, but I have done so for the purposes of comparison.

A short time ago I was appointed by the building-owner to measure the variations on a reinforced concrete building, with a firm of surveyors appointed by the contractor. The alterations were unusually drastic, and after a preliminary meeting, it was agreed that the specialists should be asked to lend us their original dimensions for the purpose of arriving at the omis-

sions. Permission was, of course, readily granted, but upon the contractor's surveyor calling for same, he was shown a small sheet of paper on which, he was informed, were the dimensions in question. Further inquiry elicited the information that the dimensions from which these *totals* were obtained had been destroyed as being of no further use.

Under these circumstances, of course, we had no alternative but to re-measure the omitted work to the best of our ability. Whether our measurements approximated to those originally taken is in the highest degree problematical, and whether the building-owner or the contractor suffered by the measurement will never be known.

I am not taking this as a typical case. I do not say for a moment that it is usual to destroy the dimensions when once the totals are obtained, but I do say that engineers, by the very reason of their profession, are not in a position to take off the quantities for their work with the detail which contractors have a right to expect. The methods of the modern quantity surveyor are the outcome of three, if not four, generations' knowledge of the theory and the practice of his profession, and it has probably taken him between seven and ten years of constant application to acquire it. The education of an engineer—with which term I, of course, include the specialist in reinforced concrete—is even more arduous, and the exercise of both professions in the person of one individual requires a Superman!

Had I the good fortune to be an engineer instead of a quantity surveyor, I should welcome the opportunity of placing a laborious, and proportionately less remunerative, portion of my work upon other shoulders. That remark at least is unbiassed.

Let us just see whether the employment of a quantity surveyor would have obviated any of the disadvantages of the various forms of contract I have enumerated.

In the first case, that of the "lump sum" contract purely and simply, the measurement of the extras by him would, I venture to think, result in a greater degree of accuracy, and would probably be advantageous from the building-owner's point of view. I have never yet been refused access to a contractor's

priced bills of quantities, even when I was not legally entitled to see them, and I do not think any contractor would refuse permission to a quantity surveyor, although he would probably—and quite legitimately—decline to hand them over to the building-owner himself.

In the second case, that of the "lump sum" contract in which the quantities do not form part of the contract, his employment would be amply justified. For any shortage in the quantities he would be responsible to the contractor, and for any excess of measurement, to the building-owner. If I am correct in saying that no responsibility is taken at the present time, the advantages are obvious, both to the building-owner and the contractor; while, assuming an error against the latter, the reinforced concrete specialist would possibly be saved a succession of unpleasant interviews.

In the third example, that of the "lump sum" contract where the quantities form part of the contract, the advantages of the introduction of the quantity surveyor are chiefly confined to the method of "taking off" the original quantities and the consequent facilities for dealing with the variations. The responsibility is less, admittedly; but I think any quantity surveyor worthy of the name would prefer to take the responsibility for the accuracy of his quantities at, of course, a slightly increased fee to compensate him for the risk.

In the last case, where the bills of quantities form a schedule only, and the building is re-measured, I rather fancy that no reinforced concrete specialist would be prepared to give the time to such re-measurement, and the quantity surveyor therefore gratefully takes the crumbs which fall from the rich man's table!

I do not know to what extent *method* of measurement may be taken as within the scope of my instructions, but I propose to touch briefly upon the point. I hope if there are any contractors present they will give us the benefit of their opinions, as it is a matter which directly concerns them, and the suggestions I have to make are purely in their interests.

I have in my office at the present time a bill of quantities, prepared by a firm of specialists in rein-

forced concrete, for a building the cost of which runs well into five figures. It consists of three items—concrete, centering, and reinforcement. It is true the latter is subdivided into three items of rods or bars in various sizes, but beyond, presumably, an inspection of the drawings, this is all the information given to the contractor.

With the greatest respect, I venture to say that no contractor, however experienced, can price that bill with any degree of accuracy, and I do not see how he can be expected to do so. I am not saying he will not make a profit on the job, but I do say that he has no idea *what* profit. I do not want to be told when I have finished that no contractor who tenders for a job, even when the quantities are issued from a surveyor's office, knows what profit he will *make*. That, of course, is obvious ; and he *does* know that he prices the bills on the assumption of a certain definite percentage of profit, which he does *not* know in the case I have just quoted.

Contractors, we all know, will price anything ; and this particular job has, no doubt, been priced on the "what I lose on the swings I gain on the roundabout" principle, at a covering price to include all the cuttings, circular work, etc., that have not been measured.

The time, however, has now arrived when bills of quantities for reinforced concrete should justify their existence and be, in fact, such as will enable the contractor to form an accurate idea of the work involved, which, in my opinion, he cannot do under the present system.

In making the following suggestions as to method of measurement, I want it to be clearly understood that I am not laying down any hard-and-fast rules. They are only advanced with the idea of obtaining the opinions of members, and if I do not go as fully into this portion of my subject as I should wish, it is because I do not want to try your patience unduly, and because I also feel that it chiefly concerns the members of my own profession, and should, therefore, more fittingly be discussed in detail at either the Surveyors' Institution or the Quantity Surveyors' Association.

The tendency under the present conditions seems to be to unite as many items as possible under one

description. From my standpoint I plead for a "separation order," and a fuller description of the work involved.

In the first place all concrete and centering should be kept separate on the various floors.

The concrete in walls, floors, beams, stanchions, stairs, etc., should also be separated. I do not consider it necessary to further subdivide the concrete. The stanchions, for instance, if octagonal, circular, or circular on square—the beams if tapering—the stairs if flewing—do not entail an additional labour (I am speaking, of course, of concrete only), and there is, therefore, no object in further separation.

It is when I come to the question of centering that the present system of preparing bills of quantities leaves most to be desired.

The prices of concrete and reinforcement are easily arrived at, and vary but little. From my point of view the centering is by far the most difficult item for a contractor to price, and it is, therefore, absolutely necessary that the description should be as full as possible and every variation and labour either measured or described.

Commencing with wall centering—if circular it should be so described, and the radius given. Then, with regard to the vexed question of deduction for openings. I believe, unless very large, it has hitherto been the custom to assume the centering went across the openings, and, consequently, to ignore them. These openings should be deducted, and a numbered item taken of centering to openings of various widths and heights—averaged where not widely differing in size, *but not otherwise*. This item I have seen measured per foot run, but, as the chief cost is that of maintaining the supports of the wall centering in which the openings occur, it is essential that the contractor should have the actual sizes—an average of the same would be incorrect because misleading.

Floor centering, of course, needs no discussion. I would only mention that all raking, or circular cutting and waste should be measured.

The centering to beams should be measured per foot super—circular being, of course, kept separate—including all cutting at angles, etc. If the beams are

splayed on bottom edge, I should measure either "Extra labour forming splay blank width on edge of beam casing"; "Angle fillet blank width and fixing on edge of beam casing to form splay"; or, take the item "Including all splayed edges"; the latter, however, I consider unsatisfactory.

If the beams are irregular or unusual in shape, I should keep the centering separate and give a sketch.

The centering to small beams, say, 18 in. girth and under, I should measure per foot run.

The centering to columns and stanchions should be measured per foot super, every variation in the shape being kept separate and fully described. I prefer to include all cutting in the description, but it can, of course, be measured separately, though I see no object in doing so.

All extra labour, such as from octagonal to square, I should number as "Extra over centering for ——" giving a full description.

Centering to stairs should be measured per foot super, as "Centering to sloping soffit of stairs." If "flewing," it should be measured separately.

All edges of concrete floors, well-holes, sides of steps, etc., should be measured per foot run giving the thickness, but if 12 in. thick or over, per foot super.

I need hardly say the description of all centering should include for all necessary strutting up from floor below or otherwise supporting.

The steel reinforcement being only of light bar, I do not think it necessary to separate the various weights on each floor. As, however, the prices of the bars vary according to size, I should, until experience taught me which sections could be added together, keep them all separate under a heading something like this :—

> The following in bar-steel reinforcement and hoisting and fixing at various levels (not exceeding blank feet from ground).

With regard to the question of bends, hooked ends, &c., I am of opinion that, where the bar reinforcement is of sufficiently small scantling to be bent cold,

they can be fairly included in the description, the labour being so small that, if numbered, they are likely to disproportionately increase the price of the steel. Where, however, they have to be forged, they should be numbered. Stirrups and ties should be numbered, giving the diameter and length of the wire.

I think it would be advisable, at the commencement of the bill, to describe such of the methods of measurement as might be open to misconstruction by the contractor, as, for instance, that all window openings have been deducted from the wall centering. This will probably only be necessary for a short time ; but until contractors have got used to our methods of net measurement, I consider that any information tending to lessen the risk of misunderstanding is wisely given.

There are, of course, many items upon which I have not touched, but I have, I think, sufficiently indicated the principle of the method of measurement I suggest to enable you to criticise it.

Should the employment of quantity surveyors become customary, it will undoubtedly lead to a greater degree of uniformity of method of measurement of reinforced concrete, as at the present time the acquaintance of my profession with yours is not of long standing. I hope, however, that this undesirable state of things, from our point of view, will shortly be remedied, when it is possible that you may find we may eventually prove a blessing in disguise, and even of some slight assistance to you, by relieving you of what I should imagine to be the least interesting portion of your work, and leaving you free to devote your time to that branch of structural engineering in which you have achieved such phenomenal success.

I apologised at the commencement of this paper for introducing a subject which, from its very nature, could be but of indirect interest to you, and I repeat that apology now. It is, however, a question which, like the front of one of your reinforced concrete buildings, will have to be faced, and you will do me the justice to admit that I have at least dealt with the matter as briefly as circumstances allow. My object has been to introduce the subject as shortly as possible, with a view to giving the maximum amount of time to the subsequent discussion, which cannot fail

to be of very great interest to the members of both professions.

Gentlemen, it only remains for me to thank you for listening to me so attentively, and to remind you that in England we have a proverb the concluding words of which are, " where angels fear to tread." (Applause and laughter.)

DISCUSSION

THE PRESIDENT (Mr. E. P. WELLS, J.P.):—

Gentlemen, before the discussion is opened I wish to read a couple of letters that I have received, the first from Sir HENRY TANNER, C.B., F.S.O., F.R.I.B.A., F.S.I., etc. (Past-President), which is as follows :—

> " I quite agree with the principles referred to by Mr. Theobald.
>
> " The practice of inviting design and tenders in open competition is, in my opinion, very unsatisfactory ; it leads to cutting down of the most vigorous kind, although the design may be within the limit laid down.
>
> " The quantities prepared by specialists are generally based on the French system, which is not very comprehensive in details. It is not unusual to find a staircase put down as one item, whether of stone or wood. This is not what we in England are accustomed to, and the results are difficulty in adjusting variations, and, I presume, in the majority of cases the building-owner suffers.
>
> " The necessity of dividing the items mentioned is of the greatest importance, because while the concrete and the steel can be ascertained definitely as a rule—not always—there is nothing to indicate the character of the false work. Therefore, while every care is taken, in regard to the first two items, to keep them within the total quantities provided, there is no interest whatever in keeping down the false work. Consequently, when a flat slab might be made to meet the case by a small addition of concrete, the

builder has to case round raking struts projecting on either side. The raking, cutting, and waste involved are patent to any one.

"There is another matter having very serious results on the progress of the work, and that is multiplication of sections differing by 32nds of an inch in diameter. The mills cannot be got to put in rolls for the small quantities involved, whereas there would be no difficulty if pains were taken to add a little to some and take off a trifle from others and adjusting distances apart.

"Under the present system the delays that take place at the commencement are appalling. The drawings showing the plans and sections, and generally the positions of the beams and stanchions, are prepared by the architect, and, together with a specification and conditions of contract, are supplied to persons indicating their desire to tender. This labour will be appreciated by architects, and adds considerably to their expenses. With the tenders are supplied some calculations and a few typical details; and the contract having been secured after examination of these details, you are at the tender mercy of the specialist, and he suits himself on the contingencies of his business as to the supply of the rest. It is the builder who is answerable to the building-owner, and the specialist can generally shuffle out of any responsibility to his nominee. The consequence is that the ordering of steel is delayed, and the time allowed to the mills is altogether insufficient in normal times.

"In my opinion, the specialist, like the architect, should be ready with the whole of his drawings, and the quantities should be properly prepared by a surveyor on the English system. How far the rods should be divided into sizes is a matter rather depending upon price per ton than on any other basis, but hoisting certainly has some small effect. I dare say the builder would put one figure to the lot, but he has the option of doing otherwise. The rod diameters should be as few as possible, and the false work, and hence the concrete placed in the forms, as

simple as possible. I do not believe in varying the proportions of the cement; this leads to difficulty and increases the responsibility of the clerk of works, and when one considers that in three or four months the concrete has perhaps doubled in strength, there is no need for such niceties and differentiation.

"If reinforced concrete building is to become popular it must be made as simple as possible, which means economy, and generally is entirely advantageous.

"My remarks have wandered somewhat from the scope of the paper, but still, they all bear on the method to be pursued in tendering. I have had experience of obtaining tenders on the basis of general drawings and quantities, omitting the competition for design, and these have shown very good results—as good if not better than those obtained when competitive designs and tenders are resorted to. This latter system does not allow the liberty of alteration that the former is capable of.

"I beg to thank Mr. Theobald for bringing forward the subject, as, in my opinion, the change is a fundamental one and must come."

The next letter that I am reading to you is from Mr. W. E. H. BURTON, Assoc.M.Inst.C.E., M.C.I. He says:—

"I am much obliged to you for your letter enclosing me copy of the paper to be read by Mr. J. M. Theobald on "Quantities for Reinforced Concrete."

"I have read the same with much interest, and regret that I shall not be able to be present at the meeting; however, I have pleasure in appending a few general remarks on the same.

"If Mr. Theobald's paper results in the quantity surveyor becoming duly recognised as a necessary agent in the carrying out of works on reinforced concrete, it will inaugurate a new era that will be hailed with delight by architects and contractors alike. Under the present system it is wellnigh impossible to secure satisfactory competitive tenders. The number of items in

the quantities issued by concrete specialists is too meagre to admit of a contractor forming a complete idea of the work required to be done. The labour in bending bars and placing the reinforcement varies much in the different systems and is a very uncertain factor, and is often misleading to contractors who have not had experience in the particular system; hence such disproportionate tendering. Again, variations appear almost a *sine qua non*, and without a carefully drawn-up schedule of quantities an equitable settlement cannot be arrived at.

"Quantity surveying has become a science only acquired by years of training and experience, and taking off quantities for reinforced concrete will call for still further attainments on the part of its practitioners. It will mean that they will have to give reinforced concrete a closer study, and be, at least, capable of checking the various schemes they handle, and advising the architect upon matters of construction and detail.

"On the other hand, the quantity surveyor will require the engineer who formulates the scheme to supply him with an infinitely greater number of drawings, particularly large-scale details, than have been considered necessary in carrying out such work in the past.

"Incidentally, it will probably lead to more engineers designing their own reinforcements, and not relying so much on the so-called specialists.

"The result will be to secure contractors a fairer basis upon which to tender, clients full value for their money, the architects more facilities in settling up accounts, and thus forward the use of reinforced concrete; and our thanks are due to the author for this able introduction of the subject."

Now, gentlemen, I will call upon Mr. Alban H. Scott to open the discussion.

MR. A. ALBAN H. SCOTT, M.S.A. (Member of Council): — Mr. Chairman, you have done me the honour of asking me to open this discussion. First of all, I think the thanks of this Institute are due to

Mr. Theobald for so kindly placing this matter before us. I am an architect, but I have also had professional training as a quantity surveyor, and it is incomprehensible to me how surveyors—and, indeed, architects and builders—have allowed certain firms calling themselves specialists to override and upset a custom which has been in the building trade so many years. In the majority of cases the method of tendering for reinforced concrete work has reverted to the unsatisfactory one in usage previous to the last forty or fifty years.

Sir Henry Tanner's most useful and instructive letter mentioned one point with regard to architects inviting or receiving competitive schemes from specialist firms. Personally, I think that if an architect did such a foolish thing as to receive competitive schemes from these firms and any defects occurred in that building when erected, the architect would be held responsible for negligence. In my opinion, it is against all public policy and entirely against the building-owner's interest to do such an absurdity. In no other form of construction would you adopt this method unless you were shirking your duty and inviting trouble. If you are asking for tenders for steelwork the architect shows on his plans full particulars as to sizes, joints, and weights, and the surveyor puts these into proper bill form, and your contractors all tender on the same basis. An architect is employed to look after his client's (the building-owner's) interests, and he cannot do this if he throws the responsibility for a portion of the work on to some other person, that person being free from legal responsibility to the building-owner.

If the whole question were not so serious, the attitude taken by some architects towards the firms referred to would be almost humorous. It is a most serious matter for the building-owner, and it is financially equally so for the surveyor. An architect loses all caste by dealing with them in the way that many of his profession do. He throws—as far as he can—the whole responsibility on to them, but by so doing he does not get rid of his legal responsibility when he employs these people either direct himself or through a building contractor.

Quantity surveyors, perhaps, to a certain extent,

have invited this position in failing to make themselves thoroughly acquainted with reinforced concrete construction. It is astonishing to watch the peculiar development. Certain firms specialising in reinforced concrete come over here and they immediately take the successful attitude of collaring the builders by getting them to pay for licences ; and this is the reason, I think, that the builders to-day are willing to put up with the inconveniences, losses, and possible gains of tendering on—we will not call them quantities, we will say, tendering on a statement, not necessarily a correct statement, as to certain material which might be employed on the building.

If you put such quantities or particulars in front of a builder for any other construction than reinforced concrete work he would not look at them ; he would say it was so absurd to ask for tenders on such information. The "statements" generally show all the weight of steel rods together. Steel rods of half an inch diameter and under cost anything up to thirty-five shillings a ton extra over the basis price. The method of lumping the concrete is equally as bad. Steel, concrete, and centering fixed in different positions have an entirely different value, and in the bill must be kept separate.

There is another big responsibility which affects quantity surveyors, too. Architects are bound legally to give their best professional services to their clients, and they are not giving these if they employ other people to do some of their part of the work. It also affects the quantity surveyor in this way—that an architect is responsible to his clients if he does not adopt the usual method and employ a quantity surveyor for reinforced concrete work, the same as for other work ; and for any trouble that might arise under a building contract, owing to his departure from the usual or established method, he is certainly morally, and I believe I am right in also saying legally, responsible, for which he has only himself to blame.

It is astonishing that a responsible architect to-day should accept the quantities from these specialists. I say "astonishing" for this reason—these persons are taking up work for which they are not qualified, and they know they are not qualified. They do not as a rule

employ men who have had training as quantity surveyors; they have assistants who have a splendid education in mathematics, and are probably good engineers; but as to quantity surveying, they know nothing at all about it, and never will unless they undergo the usual long and arduous professional training.

Mr. Theobald puts another statement forward here. He says that he knows of two buildings in which steel construction was used in preference to reinforced concrete solely for the reason that the architect could employ a quantity surveyor.

Now, this is surely a serious question for the architect. If an architect were employed and he were conscientiously of opinion that reinforced concrete was a more suitable form of construction for the particular building, then he would be legally liable to his clients for not having done that building in reinforced concrete work. I do not think there can be the slightest question about that.

Usually speaking, specialists do not attempt to guarantee their quantities—in fact, when anything goes wrong, they do not even attempt to justify them, but state that they are not infallible.

On page 439, under the heading of "1," the paper goes on to state that "unless a quantity surveyor be employed the contractors' account for extras has apparently to be accepted"; but surely whether there are quantities or not, or schedules of prices or not, any extras from a contractor can be examined in detail, and must be dealt with on *correct measurements* and at *reasonable prices*.

The author states in the next item that a certain form of lump sum contract is not quite a fair one. I think that any contract is fair if it is entered into by two sane people and provided that there is no undue pressure exercised on either party on entering into that contract.

Mr. Theobald seems to imply that he is rather vexed with these people, not so much for taking out their quantities but because they do not settle up the variations. If you assume it is necessary for them to take out the quantities, I do not think I would like to trust my clients or myself to the tender mercies of

firm's specialising in reinforced concrete to deal with the accounts or variations.

On page 444 of the paper the author deals with the subject of contractors' pricing for reinforced concrete work where lumped quantities are provided. The contractor, I am sure, does not desire to tender on lumped quantities, but he seldom has any alternative. There are, however, other kinds of contractors ; firstly, those who take, and are quite pleased to take, any loose form of quantities or contract because it gives them ample chances of making up claims. The term "claims" is used, not in its relation to variations of measurements or prices but in its wider sense ; secondly, there are the really good sportsmen, who have their bill of quantities forwarded probably through a responsible architect, and they tender for the work out of respect to him and know that they will be fairly dealt with by him ; and, lastly, there are the contractors, who do not keep analysed prime costs but rely on a broad experience to teach them an approximate overall price.

Reverting to the question of claims, there are many points that come up under this heading. For instance, in one case we had to deal with, it might interest you to know how one of these claims was made up. On the $\frac{1}{8}$-in. scale drawings which were prepared before the stresses and strains had been worked out, by some extraordinary coincidences the sizes of the beams and other members had generally been shown in widths of 6 in. and multiples of 6 in. When the accounts came to be settled up the contractor claimed the cost of extra cutting of all his centering because the sizes adopted in the building were not multiples of 6 in., and he stated that he had arranged his pricing on the assumption that 6-in. widths could be used all through without cutting.

As a counterblast to that absurd claim the building-owner insisted upon a counter-claim being put in for the cost of the omission of concrete in the space occupied by the steel. In the job in question that amounted to no less a sum than £66, which is quite a considerable item. I hesitate to believe that you could ever justify in a court of law the principle of measuring concrete where that space is occupied

by another material. I do not think the question of custom could be claimed, because there is no custom existing as to the method of measuring reinforced concrete work, quantity surveyors having failed to establish one ; so I think that the question of the deduction of the concrete where steel is used can be raised and can be enforced. I do not say it is desirable. Further, on the same question I notice Mr. Theobald advisedly uses the term " all dimensions are net." You cannot call dimensions " net " when you measure for two materials to occupy the same space.

Another expression used by the author is, " When, however, the bars have to be forged they should be numbered." I hope the surveyors will never measure that item in reinforced concrete work. I have yet to find a responsible architect who would allow forging in rods used in reinforced concrete work. Forging should never be done ; it is rather a pity it should be put in the paper as even a possible contingency.

From one statement made in the paper one is led to think that the author is under the impression that the Concrete Institute consists only of people who are pleased to call themselves reinforced concrete specialists ; but although there are a few specialists, it has a number of architects, surveyors, and a good many engineers ; and no matter how much or how little these know of reinforced concrete construction, none but the " specialists " desire to be called anything but architects, or surveyors, or engineers, as the case may be.

I do not want it to be understood that the Concrete Institute is limited to those known as reinforced concrete " specialists " who are in many instances mainly *steel-merchants*. Some of the " specialists " are my personal friends, but the attitude they are taking to-day towards architects, surveyors, engineers, and contractors is a little beyond a reasonable man's endurance, and it is certainly against the interests of the building-owners.

In conclusion, I would like to refer you to the Articles of Association filed by some of the specialists. I think you would be very surprised to find that steel-work and other trades are associated with almost every profession under the sun.

Will you allow me to propose a most hearty vote of thanks to the author of this most interesting paper.

MR. T. A. WATSON, M.C.I. :—Mr. Chairman and gentlemen, some few days ago, to my sorrow, I received an invitation from the Secretary to take part in the discussion to-night. Not being a particularly good speaker, I am afraid it will be to your sorrow also. However, I appreciate the honour, and will endeavour to say a few words. The author of the paper has, I consider, given us a particularly happy one. He has dealt with the subject in a very breezy manner and practically settled it all offhand.

The condition of affairs that exists at the present time between the quantity surveyor, the architect, and the contractor is the natural outcome of the introduction of reinforced concrete into this country. That it is bad in some respects there is no doubt, and it should be remedied, and the method which the author suggests is, in my opinion, a very happy one.

I particularly like the phrase in his paper in which he says, "The clients must wait." I think that, at the present time, there is far too much undue haste in the preparation of reinforced concrete schemes, and sufficient time is not given to the contractor or the reinforced concrete specialist to prepare and price the various schemes ; and anything which will tend to give more time to the contractor and to the reinforced concrete specialist will be, in my opinion, a boon, even if it extend to the waiting of the client. There is one thing which Mr. Theobald's suggestion, if it is carried out, means, and that is practically the abolition of competition between various reinforced concrete specialists, and I think that is a very good thing. As far as I can see, if Mr. Theobald's scheme is carried out, the architect or the building-owner will have, first of all, to decide on a firm of reinforced concrete specialists to carry out the work, or an engineer to design the work, and that, I consider, is something very useful gained.

AN HON. MEMBER :—So he ought.

MR. WATSON :—The present-day system—from which I have suffered, and my firm as well—in which

we have been invited to tender on four or five schemes drawn up by different "specialists" for one particular job, means that we have to price one job four or five times over, and then perhaps not get it; and we have had the expense of this extra labour, that might have been saved had the course suggested by the author been adopted.

There are some difficulties in the way of carrying out the scheme, one of which is the difficulty that the reinforced concrete specialist or the engineer will have in preparing detailed drawings of the work in time to satisfy the client, and in time for the quantity surveyor to take off his necessary particulars, because the details of reinforced concrete are very considerable, and the number of bars and the number of bends in the bars and the weight of the bars necessitates a lot of arduous work on the part of the engineer, more so than it does in steelwork construction; and if the building is in a hurry, I am afraid that the only method of dealing with the reinforced concrete quantities is by the suggestion which Mr. Theobald has numbered "4"—*i.e.*, a lump-sum contract in which the bills of quantities form a schedule and the entire building is re-measured. The author says that unless under circumstances where the erection of the building in the shortest possible time is of vital importance, this method seems needlessly extravagant. With this I cannot agree. I think, undoubtedly, it is the best way, it is the simplest way, it will expedite the work, and it really brings no hardship either on the contractor or the reinforced concrete specialist, because it gives the "specialist" the necessary time in which to prepare proper working plans and detailed drawings, while the quantity surveyor is taking out approximate quantities from preliminary rough plans previously prepared by the engineer or reinforced concrete specialist, giving the weights of bars, sizes of beams, etc., sufficient to enable the quantity surveyor to take off approximately the correct amount of steel and concrete.

As regards the latter part of the paper, the method of taking off the quantities, on that I have nothing to say. The quantity surveyor is an expert in taking off centering, and I have no wish, and I do not sup-

pose any reinforced concrete specialist wishes, to take that work from the quantity surveyor.

I should like to congratulate Mr. Theobald on and thank him for his paper; it is one which I have listened to with very great interest. Before sitting down, I should just like to say a few words with regard to what the last speaker said. The last speaker has spoken in anything but respectful terms of the engineer.

Mr. SCOTT :—I said the reinforced concrete specialist. I did not say the engineer. They are two different persons entirely. The engineer I call a professional man; I do not call the "specialist" a professional man; he is in many cases in reality merely a dealer in steel.

Mr. WATSON :—Seeing I misunderstood the gentleman, and the character of the engineer is cleared, I do not think I will take up the cudgels on behalf of the reinforced concrete specialist; I will leave him to do that himself. The last speaker also attacked his brother-architects, and I think that they should not be slanged quite so much, if I may use the expression, because I really think that the present condition of affairs is merely the natural outcome of the adoption in this country of reinforced concrete, adopted because it was a more economical form of construction in many instances than the construction that obtained in the days before its adoption. Gentlemen, I thank you very much for listening to me; I did not intend to say so much.

Mr. A. G. CROSS, F.S.I., Hon. Secretary Quantity Surveyors' Association :—Mr. President and Gentlemen, I must first thank you, Sir, and the Council of the Institute for inviting me to be present to hear Mr. Theobald's paper. As Mr. Watson says, Mr. Theobald practically settled every question for us. There is one point I do not think he sufficiently emphasised, and that is the advantage which accrues to the building-owner from the employment of the quantity surveyor. After all, it is the building-owner who provides employment for the architect, the engineer, the quantity surveyor, or the "dealer in steel"; and his interests should be our first consideration.

I am afraid it is a little difficult to persuade the man in the street that, in advocating a continuance or an extension of that system by which he lives, a quantity surveyor is absolutely unbiassed ; but I think the fact that the system of contracting on quantities has prevailed pretty generally for the last hundred years is sufficient evidence that it is appreciated. In my opinion, an inestimable advantage accrues to the building-owner by the employment of the quantity surveyor, and the quantity surveyor having been employed, it is his duty to see that quantities for every item embraced in the building or engineering structure upon which he may be engaged are provided. By no other means can the value of artificers' work be accurately estimated ; in fact, the surveyor's opinion upon any question of value is usually worthless until the quantities are prepared for the particular building. In my view, there is nothing in either the workmanship or the materials of a reinforced concrete structure which, from its nature, cannot be measured and its value estimated by the surveyor's usual method of picking a completed building to pieces and measuring each item of which it is constructed.

Another argument in favour of the employment of the quantity surveyor is that the provision of a bill of quantities usually results in a lower estimate being obtained. This in itself is of advantage to the building-owner, although we have heard it contended —I think Sir Henry Tanner does so in his letter tonight—that any system which tends to increase the competition for a method of construction which relies, as this does, upon the use of the best possible material, and of the best workmanship, is to be deprecated.

Some people appear to be apprehensive lest the extension of competition for this method of construction may result in the work being undertaken by the general contractor to the effacement of the expert and the specialist, by whom, in my opinion, this work should be undertaken. I do not think there is any ground for any uneasiness on that score. At the moment there are very few general contractors who would care to undertake this work without the intervention of a specialist, and those who do so would probably sublet the work to those who specialise in

this form of construction, or else would have in their employ assistants who are skilled in its construction, under whose supervision the work would be carried out.

The introduction of reinforced concrete into this country seems to have caused as much consternation as did the spread of Christianity among the silversmiths of Ephesus, when Demetrius, finding his craft imperilled, called a meeting of his fellow-craftsmen and proceeded to create a terrible uproar. I have this, sir, on the authority of St. Paul.

I think we are only repeating the experience we gained between the time when steel construction was first introduced and the time when its use became general. For some years it was the rule rather than the exception to get a price from a steel-construction contractor and include that in the builder's tender without any quantities and without any competition ; but gradually that system has been superseded by the practice of the quantity surveyor preparing the quantities for steel construction, and the items being included in the general bill in the usual way.

The system adopted by an architect with whom I have been associated for many years with regard to steel construction is this. He always has the quantities prepared, and the bill added to the general bill in the usual way, a proviso being inserted that the steel construction is to be carried out by one of the following firms—enumerating half a dozen leading contractors who specialise in steel construction. The builders in that case would naturally invite competitive tenders and accept the lowest. It seems to me, Sir, if that system were adopted with regard to reinforced concrete that the objections of those who are afraid that the work will be carried out by those who are least competent to do it will be overcome, and the building-owner should at the same time secure a certain amount of competition for the work for which he is paying.

I think there are very few other points upon which I propose to touch in Mr. Theobald's admirable paper. He had something to say about alterations and variations. I always thought that this particular system of construction did not lend itself to alterations. Now, I quite agree with him that unless the

quantity surveyor is to be provided with the original dimensions from which the quantities have been prepared——

A MEMBER :—If they are not burned.

MR. CROSS :—If they are not burned his work would certainly be, as he described it, an acquired taste ; in that respect, I presume, he suggests that it would resemble, shall we say, Astrakhan caviare, or olives, Browning's poetry, or Meredith's novels.

In conclusion, I should like to congratulate Mr. Theobald on his paper, and to again thank you for allowing me to be present this evening.

MR. S. BYLANDER, M.C.I., Chairman of Junior Institution of Engineers :—Mr. Chairman, I am afraid I have very little to say on the subject, which I know so little about. I never attempted to make any quantities, but I have seen a good many. There is one thing which I believe to be of very great importance in regard to the engineer and contractor (and I am sure also the architect)—that is, a "system of simplicity."

Now, gentlemen, we have a chance of making a standard and forming a standard without basing same on precedent, and I think that we should try to make it as simple as possible. How this can be done I am not prepared to say, but when I first saw the quantities for reinforced concrete prepared by a specialist it occurred to me it was made in a very simple way—namely, unit prices or unit quantities. I think that could be adopted with advantage. For instance, so many square feet of floor at certain thickness and so many foot run of beams of certain sizes. I also think that we might, in the quantities, state the weight of steel per foot run instead of the total weight of steel. We might also state the number of bends per ton of steel, also, of course, stating the size of the bars. It is very convenient for contractors, I think, to price a bill of quantities which contains as few items as possible ; still, the different items should be separated so that they could be properly priced. As the author explained, this is particularly a question of difference in cost. Centering for curved work and

straight work should be kept distinctly separate. The size of beams, of course, affects the cost of centering per square foot ; therefore the size must be given of the finished member.

With regard to separating the items for different floors, I do not think it is so necessary, perhaps, for an ordinary sized building, but it is very useful to have the different quantities just the same.

I am in hearty agreement with Mr. Watson and his suggestion that quantities for reinforced concrete should be taken out provisionally, and the prices to form a basis of future remeasurement. I think that is an exceedingly practical way of dealing with reinforced concrete. I appreciate, being an engineer, how very necessary it is that you should have sufficient time to prepare the necessary details. In reinforced concrete more than any other constructional work, I think, it is necessary that the drawings should be complete and clear.

In conclusion, I think I shall ask the quantity surveyor, when he finally prepares his quantities, not to forget one thing, and that is to provide a provisional sum for the payment of an inspector or a clerk of works, properly qualified and certified by the Concrete Institute to be capable of seeing that the work is carefully carried out according to drawings and good practice. Then I do not think we need be afraid of putting the work out to competition to different contractors for fear of unsatisfactory work.

Mr. T. E. BARE, Vice-President Quantity Surveyors' Association :—As a quantity surveyor, Sir, I naturally sympathise with my friend Mr. Theobald in the views he has put forward in his paper. I think we might all assume that everybody will be better off by the employment of quantity surveyors when tenders are required for reinforced concrete and for the proper adjustment of varied or extra work. The chief difficulty seems to me to be the question of time, if it should be really necessary to wait for completed details before quantities could be prepared, particularly with regard to the steel reinforcement. Sir Henry Tanner referred to this question of delay in his able remarks upon Mr. Theobald's paper which

have been read to us. I find, however, the method which has been in common use in quantities issued by specialists is to give the weight of steel, calculated approximately at so many pounds per unit, whether it be per square yard of floor or per foot run of beam, and so on. Such given weights, presumably, are based upon known constants of work actually executed or from elaborate mathematical tables to which the engineer or specialist refers, but certainly not upon the actual quantities of steel "taken off" from the detail drawings. It is to be supposed that these fixed weights, per unit, which are not subject to any re-adjustment, err, if anything, on the right side for the contractor; but it might possibly be the other way, and I would suggest with regard to the steel—and, perhaps, the steel only—that provisional quantities should be given in the bills, calculated, in the same way, from constants figured upon the drawings of the general scheme, and we should not then be in a difficulty with regard to the detailed drawings not being prepared in time. I think that a fair estimate of the amount of steel that would be required could be arrived at in this way.

Well, then, at some time or another, I was going to say, it would have to be clearly stated what steel is required. For instance, I suppose that on each detailed drawing there would be a schedule given of the steel required for each particular section of the work, and, indeed, such schedules must go to the manufacturer so that the steel for each section can be separately delivered in bundles, it being impossible to sort steelwork out if it were delivered pell-mell. In that way it would be easy afterwards and at leisure for the quantity surveyor, from the details, to ascertain the weight of the steel that had been actually used, and I think that is one way of getting over the difficulty.

I think as regards other matters in Mr. Theobald's paper, the gentlemen who have previously spoken have anticipated what I had to say. One thing, however, I would say, and that is in all probability, if you give the quantity surveyor the job, the contractor would get a better presentment of the centering required than he now does, which seems to me to be a very important thing.

MR. W. G. PERKINS, District Surveyor for Holborn (Member of Council):—Sir, there are many quantity surveyors here present to-night, and I think they could deal with this question better than I can, but I should like to criticise the remarks of one or two of the speakers. The last gentleman has suggested that you should ascertain the amount of steel in a job by the use of constants. That would be all very well if the quantity surveyor described or gave the amount of concrete used in so many square feet of a certain sectional area. But I do not think he does that. He puts it into feet or yards cube, and we do not base our percentage of steel upon the cubic yards of reinforced concrete, but upon the sectional area of the beam or the slab with which we are dealing. For that reason I do not think we can use constants in the way suggested. Then, Mr. Bylander suggested that a sum should be provided in the quantities to be paid to an inspector or clerk of works. If the builder has to pay the inspector or the clerk of works, then that inspector becomes a servant of the builder, and I think that method of payment undesirable. The inspector should be paid direct by the architect or the client.

I am inclined to agree with a "good deal" of what Mr. Alban Scott has said as to the "specialist," although I do not go quite as far as he does. I think what we really come to is this, that the architect should learn a little about reinforced concrete (hear, hear). He should be able to design his floors, his beams, and his stanchions in such a way that he will be able to show on his drawings approximately the number of bars, their arrangement, and their diameter, the amount of reinforcement to take diagonal tension, and so on. The quantity surveyor is then able to measure it and put it into his bill. That would give the builder something to price, and form a basis upon which to measure extras and omissions.

Turning to the question of measurement, Sir—this is getting to a part of the question which has not been discussed to-night—I think that the centering of floors should be dealt with in a little more detail than Mr. Theobald suggests. One case that occurs to me now is this: you have a square hall, such as

we are now sitting in ; in that hall you have a gallery going round, perhaps, three parts of the way ; you start at a certain level at one end, you have to rise all round, and as you work back into the angles you get all sorts of different curves, both in your floor slab and in your beam centering. A floor of that description, I think, should be kept apart, and not only described, but sketches and sections showing the various sweeps and bends should be added to the bills of quantities.

Just one word more, Sir, and that is this : I think the steel which we get in helical or other curved reinforcements should be kept separate from the straight. Mr. Theobald does not suggest that, but I think it should be done, and in dealing with helical reinforcement the diameters of the columns should be given. For instance, you would have so many hundredweights of steel of a certain diameter wound round the vertical bars, stating the number in a column of such and such a diameter, or so many hundredweights round so many bars of a column of some other diameter. I think we are very much indebted to Mr. Theobald for having brought the matter before us.

Mr. R. M. KEARNS, F.S.I. : Mr. President and gentlemen, I feel, like a previous speaker, that much that I had intended to say has already been anticipated. I shall fall back upon a few notes to see what remains to be said. I quite agree with Mr. Theobald in advocating that quantity surveyors should prepare the bills of quantities for reinforced work, but it seems to be generally understood that the specialist firms insist on the use of quantities prepared by their own experts. This is not a satisfactory state of things, as it is doubtful whether such quantities represent the exact amount of materials, more especially as to the reinforcement, actually put into the building—apart, of course, from the question of extras or omissions—as the detailed drawings are only forthcoming as the work proceeds. The client is, therefore, in a position somewhat similar to that of the man who buys "a pig in a poke." Moreover, it is highly probable that the client would obtain closer and more favourable estimates from contractors if they were

supplied with bills of quantities which would give them a reasonably accurate idea of the work required to be done under the terms of the contract.

The matter is one of deep interest to quantity surveyors, for it is evident that the employment of reinforced concrete is rapidly increasing. Note, for instance, the important building, his Majesty's new Stationery Office, now being erected in Stamford Street. We may see on that site a lofty mass of steel gantries ; we may watch the travelling cranes moving smartly backwards and forwards in response to the mysterious and silent power of electricity, and, like the man in the street, be lost in wonder and admiration. All this machinery, poised in mid-air on tall, slender supports, suggests, indeed, the vision of a " baseless fabric " which, as Shakespeare expressed it, will dissolve and " leave not a rack behind." In this case, however, it will leave a spacious and substantial building resting on reinforced foundations—a building which will no doubt be closely studied by prospective builders of warehouses and structures of a similar type.

With reference to the items proposed to be inserted in bills of quantities, I regret that I cannot agree with Mr. Theobald on every point. My idea—and I am not unsupported—is that labour items should be discarded as much as possible. They are likely to be over-priced, so far as the centering is concerned, the latter, to a large extent, being only chargeable as " use and waste." It is not customary to measure the labours on centering in connection with the stonework in Gothic window and door openings. Why start a new system?

Briefly, I would suggest that all the concrete walls and floors should be supered, keeping each floor separate. We are not likely to get, in the near future, any walls or floors exceeding nine inches in thickness. The concrete in beams and piers might be cubed.

The centering to walls and floors should be measured over all surfaces and billed at per square or foot super. Door and window openings to be treated as suggested by Mr. Theobald. The casing to beams and piers, cornices, jambs, etc., might, with advantage, be measured at per foot run, stating the girth and giving

a figured section in the margin of the bill showing any angle fillets or splay cutting.

The different heights from floor to ceiling and from floor to soffit of beams should be stated at the proper place. This is of great importance to builders when tendering.

With reference to the reinforcement itself, I would suggest that the whole of the steel bars, loops, stirrups, or ties should be weighted and billed at per hundredweight. There should be no numbered items. One might as well attempt to number the nails when measuring carpenters' work as to number the labour items in reinforcements. When wire is used for binding it need not be measured, but should be mentioned, like the forging and bending of bars, in the general description. In short, the price quoted per hundredweight for the reinforcement should cover the whole of the smiths' materials and labour. Where there are many beams, the reinforcement for which can be put together in the smiths' shop on the site, the fact should be stated.

It should be borne in mind that bills of quantities are only the means to an end—namely, the sum for which a contractor will undertake to do certain work. It is an advantage to all parties if the quantities are clear and explanatory, but they should not be too elaborate, and thus lead to difficulties and unnecessary expense in connection with the admeasurement of variations. And in these days of feverish haste and rapidly changing requirements in most departments of life, variations in contracts are absolutely unavoidable.

Mr. W. E. DAVIS, Member Quantity Surveyors' Association : — Mr. President, Mr. Theobald, and gentlemen, I think we ought to thank the last speaker for really dealing seriously with the measurements, however much we may disagree with his methods. The first speaker, Mr. Alban Scott, rather abused the quantity surveyors because they had allowed themselves to get into the position they had ; but I think the unfortunate quantity surveyors had no opportunity of doing anything else. Foreign firms came over—it is well known that the earlier systems of reinforced concrete were brought over by foreign specialists—

there was an air of mystery about them, and their work was looked upon as something quite beyond the ken of an ordinary architect ; and I think that that possibly accounts for it getting out of the hands of the quantity surveyors.

Another question is—and I think that in this all quantity surveyors will agree with me—why on earth the poor unfortunate quantity surveyor should always be the one to suffer for delays. There seem to be two points ; there is the one from the time the client thinks about building, and then there is that at the end, being the time when he wants the work finished. The client hesitates and hangs about a bit, and (I suppose amongst quantity surveyors it should be whispered) possibly the architect is not quite so expeditious as he might be. (Hear, hear.) And then we come to the other end, the work has to be finished by a certain date, the builder cannot do it in less than a certain time, and so the quantity surveyor is between two solid walls, as it were, and has got to be squeezed in in that time, so that if anybody is to be left out it seems to me that the quantity surveyor is frequently the one to suffer.

But I am sure if the building-owner could only be persuaded of the advantage it would be to employ a quantity surveyor, not only on the mere question of value but the trouble it would save, he would do so. How many building-owners say they have built once and they do not wish to do so again because of the trouble they have had, the litigation and trouble in finishing up, which would, I think, in nine cases out of ten have been avoided by the employment of a quantity surveyor.

I think Mr. Theobald's suggestion for measuring would meet with everybody's approval. I have had to do some of this, and I have found that subdividing the steelwork in sizes and then keeping that in loops and the spiral work separate gave satisfaction. I asked the tenderers afterwards whether it met with their views—it was in the early days—and they said it gave them all they wanted. I have since continued the practice and have not had any question raised. But the contractor simply pooh-poohed the idea of numbering bends.

With regard to the centering, I certainly cannot agree with the last speaker, and I think most quantity surveyors will agree also, that the cuttings should not be omitted. But there is one point that I have always had a difficulty about, and that is the re-use of centering. You get a warehouse with, perhaps, five or six floors; now, it makes a very great difference in the cost of the centering as to the number of times it can be re-used on the same building without a large allowance for waste. If any suggestion could be made as to how that could be dealt with in a bill of quantities, I think it would be useful. I am sure we all, quantity surveyors especially, and if the truth were known, architects and engineers also, would thank Mr. Theobald for laying down some definite lines for measuring. I think the time of the reinforced concrete "specialist," with his fancy systems, is going by. He is undoubtedly getting out of date. There are many systems now, and engineers and architects are beginning to understand the material, so that there is no need for the specialist. Consequently the quantity surveyor will have an opportunity in the future, when the work can be put to open competition, and not left in the hands of the few. I thank you, Mr. President, for the opportunity of speaking.

Mr. GEORGE CORDEROY, Assoc.Inst.C.E., F.S.I., M.C.I.:—I thank you, Mr. President, for the opportunity of speaking and congratulating my friend Mr. Theobald on the paper. I did not come here intending to speak to-night, and I regret I have not heard Mr. Theobald read his paper, though I have looked through it since I have been in the room. I congratulate him all the more upon his courage in tackling the subject, because I personally drew back from the task. I have an infinite repugnance to write papers on quantity surveying. I find it sufficient to have to write the bill.

The difficulty which is experienced in taking out quantities for reinforced concrete work really, I think, resolves itself into this, that the system of reinforcement to be pursued has so seldom been settled before the tenders have been invited. The practice which has largely prevailed hitherto has been

to invite estimates for various systems of reinforced concrete for the same building or for the same structure. As I said once before in this room some months ago, the difficulty that has pursued both the quantity surveyor and persons tendering is that it is rather a war of systems, or has been hitherto rather a war of systems, than the laying down with definite knowledge by the architect or the engineer as the case may be of a system to be pursued.

I have had to deal in the course of my practice rather extensively with reinforced concrete work in different forms, monumental buildings, warehouses, jetties, and wharves, and in the present state of knowledge and in the present welter of systems it is not possible to lay down any absolute method of measurement. The method of measurement which would apply to a monumental town hall is entirely inapplicable to a warehouse, and the method of measurement which would apply to a jetty is rather different from either. What it really comes to is this, that the trained professional mind of the surveyor must be applied to the circumstances before him, and he must produce a bill of quantities which will present in an ordered form the varieties of work which have to be done, having due regard to the methods of construction which will be employed in connection with the particular system which it is anticipated will be used.

I have had also, Mr. President, quite recently to prepare a schedule of quantities or a schedule of prices which really consists of an approximate bill of quantities with a view to subsequent measurement for the construction of a building in which the parties tendering were each to state their own system. There were 26 parties tendering, and I think there were more than 26 systems tendered for. I am not quite sure about that, but, at any rate, some of the parties tendering were very liberal in the number of systems which they suggested, and tendered for two or three. The building has not yet been carried out, and I am looking forward with great interest to the time when I have to measure under the system which will ultimately be selected.

Now, the preparation of a schedule of that kind is merely a *tour de force*. It was required and insisted

on in that individual instance, and it does not resemble what my friend Mr. Cross or the writer of the paper would regard as a bill of quantities. It has to be something of an entirely different nature to what we ordinarily mean or a surveyor ordinarily means by a bill of quantities, which is an analysis of the component parts of a designed building.

It is a surveyor's duty to prepare in ordered form the analysis and statement of a settled fact. Now, a building or a structure of any kind tenders for which are invited under those conditions does not coincide with that description, and I agree with one of the speakers who said that he thought that what was really wanted, and what was really needed, was a better apprehension on the part of those designing buildings and other structures of the nature and properties of reinforced concrete work and a better understanding of its design, and I believe the time is coming (in fact, I believe it is at hand) when engineers will design in reinforced concrete, as they have hitherto designed in iron, stone, and brick, and when architects may perhaps do the same.

I, personally, am not very sanguine of the extensive application of reinforced concrete to domestic or civic architecture. I would remind gentlemen here present that very distinguished men had a try thirty or forty years ago at concrete building. There is one in the Broadway now, one of the most dreary and miserable-looking buildings I know, but designed by one of the most distinguished architects of that day.

MR. W. R. HOOD, F.S.I., Past President Quantity Surveyors' Association :—Mr. Chairman and gentlemen, I scarcely expected to be called to speak upon this subject until the adjourned meeting, but as you have called me I do so with pleasure. The subject is one which interests us as quantity surveyors particularly, and in so far as we are discussing it this evening, as to whether we, as quantity surveyors, should prepare the quantities for the general contractor rather than that the specialist should do it for us, we may in the near future have that question settled for us whether we wish it or not by an outside

agency, and that is by the public authorities for whom we work. I speak from personal experience, and I have no doubt it is the experience of many others in this room also, that the detailed quantities have to be taken out for special work, for which, up to recent times, provisional sums have been put into the bills of quantities. I think we should certainly welcome that, although up to the present it has involved rather less labour than will fall to our lot in the future ; and, I think, in reinforced concrete work we shall have to do the same as we have done hitherto with constructional ironwork.

The remarks of Mr. Alban Scott were very interesting, and some of his utterances struck very hard, and no doubt reached the target in a great many cases, and in some cases probably fell short ; but, at the same time, I think they have given most of us material for thought.

The subject of the paper that Mr. Theobald has read will certainly lead to considerable discussion in the future in another place—in fact, in two places ; for I certainly consider that the Council of the Surveyors' Institution should feel it incumbent upon it to call a meeting of its own members and the Quantity Surveyors' Association, and, with the assistance of the reinforced concrete specialists, to formulate a system of measurements which will be generally adopted. I think the sooner that is done the better, since, no doubt, there are a great number of different ways of measuring reinforced concrete work. There is great probability that, if all the quantity surveyors in this room had the same set of drawings and specifications from which to measure, they would produce bills of quantities that would differ very considerably, although possibly, in the end, the general contractor would be able to price them equally well. But if we could standardise the system of measurement, I think it would be to the advantage both of the building-owner, the quantity surveyor, and of the general contractor.

I think, also, that the employment of a quantity surveyor in this matter would be of considerable advantage to the building-owner, who, of course, is the first person to consider.

There is undoubtedly an element of speculation in the present system, although a speculation with only one side to it, I am afraid, is scarcely a speculation; but still, there is only one side to it, for the reason that if a "specialist" is invited to give an estimate for a particular system of reinforced concrete work he naturally takes out the quantities in such a way as to cover himself for any contingencies that may take place, and therefore the estimate which he produces is probably not an accurate estimate of the work which has to be carried out. Another subject was referred to by Mr. Theobald—viz., variations in the general drawings and the detailed drawings after the quantities have been prepared by the "specialist"; those are the words, I believe, of the paper; naturally, variations should be adjusted, either before the estimate is accepted or at the completion of the contract; and if he does not adjust those variations, who is going to get the benefit of it? Undoubtedly, the reinforced concrete specialist, not the building-owner. With regard to the point Mr. Theobald mentioned in his paper where he met another surveyor, and they endeavoured to get the original measurements from the "specialist," and that gentleman gave him a few figures of totals, Mr. Theobald says he would not tell, and naturally he would not tell, who got the benefit of that transaction; but I can make a very shrewd guess, and I think most of us could do so; there is no doubt but that the building-owner was not the man who got the benefit, so that the easier access we have to the original dimensions the better for all purposes; and I think that the sooner the members of the Surveyors' Institution meet—and I hope that Mr. Corderoy, whom I see present (being a member of the Council of the Surveyors' Institution), will do his best to bring about this meeting of those particularly interested in the subject, and get a standard method of measurement agreed—the better we shall all be satisfied.

THE PRESIDENT (Mr. E. P. WELLS, J.P.):—There are a great many more wishing to speak on this subject, and as at the next meeting, on December 12th, we shall be short of one of the papers, I

propose to adjourn this meeting, to then continue the discussion, and also to listen to a paper by Mr. Laurence Gadd, F.I.C., on "The Effects on Concrete of Acids, Oils, and Fats."

But before we adjourn I should like to say a few words, as there are so many quantity surveyors present, just to give you an inkling as to how to proceed by way of coming to a common agreement on taking out quantities for reinforced concrete work. And when you are all, I hope, here on the 12th of next month, there will be something more to talk about, and I think we may look forward to a fairly healthy discussion.

I will now show you the method I have adopted for several years in taking out quantities, and as a rule you can take the original quantities, if they are asked for at any time, and you can check every measurement from start to finish. For example, a building is to be put up ; it does not matter whether it is an ordinary building or an engineering work, or what the nature is. Take, for instance, one thing only —a column, and we will assume, for the sake of argument, that we are dealing there with the base inclined at an angle of 45 degrees. In taking out quantities, this is the method I adopt : I have paper that is specially ruled divided up in columns as follows [illustrating on blackboard], and you will now see the simplicity of the method. We will just say, for the sake of argument, that this first column represents concrete, the next represents shuttering, the third represents steel, the fourth represents the abstract or the analysis, this is the rate column, and the last is the total in pounds, shillings, and pence ; so what we have is this—every detail of the quantities from start to finish, the whole analysis, the rate of the bill, all staring you in the face in one operation. It is not a case here of taking out quantities all over the place, then starting afterwards and abstracting them, and that is where so many mistakes are made.

Now, for instance, we will take out the first item—concrete. We will give its area by its thickness and reduce it down to cubic feet. We come along to the next column—the measurement for shuttering [illustrating]. Now, if the angle is 33 degrees, shuttering for that base is not required, as the concrete will

stand up, but if it is to be 45 degrees the concrete will not stand up ; therefore it becomes necessary to put a subheading under "shuttering," for the simple reason that the extra cost of making the shuttering on the splay is caused by the cutting of the angles and the holding of the whole together.

We pass next to the steel column, and the whole of the steel is shown—sizes of bars, their lengths, their weights, and also the shear members. This gives us the weight of the steel in the base.

Now, this finishes the base of the column, with everything taken out—its concrete, its steel, its shuttering, both plain and splayed. You then carry the totals into the abstract column, also if there are any labours ; but, as a rule, in column bases they are absent. When you take out your proper bill of quantities, you have everything here for your abstract, not having to go back to, say, sheet 22, or any back references being necessary.

We will now take the column shaft ; the same method applies. You first take the concrete, then the plain shuttering, the splayed shuttering under a separate heading ; then take the steel in plain rods and any hooping or linking under separate headings, all of which is abstracted in the fourth column, as well as any extra in labour, etc.

Now, the same method applies in all descriptions of works. If by any possible chance there is any circular work, it is taken as an extra per foot super on the ordinary work. When it comes to windows, I always make the deductions for the window area, and I state in the quantities that everything is net, notwithstanding any trade custom to the contrary. Now, this system is followed out in its entirety from start to finish ; reinforced concrete quantities are the easiest to take out of any work that I know. I am speaking now with an experience of over forty years since I first started taking out quantities ; then it was in wrought-iron work ; steel was not known. I have gone through the whole gamut up to the stage of reinforced concrete, and I say this : there are no quantities so easy to take out as reinforced concrete work, if you go on a system, and you must have a regular system to do it.

But I should recommend that all quantity surveyors should depart from their usual method of taking out quantities for this work. When concrete is given, it is far better to do it in cubic feet, except you have got mass concrete, than in cubic yards. If you have ordinary shuttering, you give it in square yards ; if it is special work, let it go into square feet. You keep your splayed shuttering all separate from your ordinary, because, as a rule, the value of this is three to four times the value of ordinary straight shuttering—that is to say, that if you take a floor shuttering, as compared with a column shuttering, the value of the latter is nearly twice as much.

It is the same thing as regards external and internal shuttering in hopper bottoms for silos. I have seen the foolish builder putting the price down at 1s. per square yard, including all his profits, and he was not content with that, but took his internal at 9d. When all the information is given to a builder and he puts down prices like these, he has only himself to blame for any mistake he makes, and then the subsequent loss of money. I have known a builder quote for hopper shuttering at 2s. 6d. per square yard, when I know that every square yard he put in cost him 7s. 6d. The reason why these mistakes are made so constantly is this, that very few people understand how to price the costs in their tender of the labours, and their relation to the strutting, and reduce that down to a super-measure. When once they have learned to base the prime costs, starting from iron ore as an example, then work it right up to the pig, then cost of manufacturing, etc.—when, I say, they have learned that thoroughly they will not make the mistakes they do at the present day.

In adjourning the meeting, I have just a few words more to say. If anybody at the next meeting has any suggestions to offer, by which they can simplify the taking out of quantities, I should be glad if they will do so. And what I also recommend is this—that beams, columns, and floors be kept all separate from the foundation upwards ; separate them all through, so that when the time comes to measure up there will be no difficulty whatever in following the working, and a child, even the office-boy, can follow the work.

Another thing I should recommend is this, that when the bills of quantities are got out, instead of putting, as is general, in the left-hand column of the quantities the superficies, etc., I should give the number of the item, and at the end of the description the yards cube or feet cube, etc., as the case may be, so that if at any moment a question arises, What do you mean by item 190? you can give it, and you do not need to turn to page 54, tenth line, etc. It is a rapid means of getting to work; it simplifies everything, and that is, I think, what Mr. Theobald would wish. And if you, as quantity surveyors, would do likewise—that is, take out quantities in such a manner, then any one can follow them; any other quantity surveyor can take them up and, getting hold of the working drawings, can follow them up from start to finish.

The discussion is adjourned till Thursday, December 12th, at 7.30 p.m.

TWENTY-NINTH ORDINARY GENERAL MEETING

THURSDAY, DECEMBER 12, 1912

THE TWENTY-NINTH ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held in the Lecture Hall at Denison House, 296 Vauxhall Bridge Road, Victoria, S.W., on Thursday, December 12, 1912, at 7.30 p.m.

MR. E. P. WELLS, J.P., President, in the Chair.

THE PRESIDENT (MR. E. P. WELLS) :—Gentlemen, the first business we have before us this evening is the applications for membership. They have already been before the Council and approved, and I will put the several names to you, and unless I hear to the contrary I will assume you agree to their being elected :—

1. MR. WILFRID LAWSON CARTER, B.Sc., M.S.A., Southend-on-Sea.
2. MR. RICHARD COLLINS, M.I.Mun. and C.E., Engineer and Surveyor to Enfield Urban District Council, Enfield, Middlesex.
3. MR. CHARLES HEATON FITZWILLIAM COMYN, A.R.I.B.A., M.R.San.In., London, E.C.
4. MR. JOHN THEODORE GILBERT, Surveyor, London, W.
5. MR. WILLIAM WHITTAKER GOULDING, P.A.S., Manchester.
6. MR. EDWIN PALSER, Licentiate R.I.B.A., London, W.
7. MR. JOHN PARHAM, Mem.R.San.I., Enfield, Middlesex.
8. MR. ARTHUR JAMES PITMAN, London, S.W.

9. Mr. Robert Orr, A.R.I.B.A., P.A.S.I., London, E.C.

10. Mr. James Enos Streadwick, Kingston, Jamaica.

11. Mr. Rudolph Nielsen Stroyer, M.Inst. C.E. (Denmark), B.Sc.Eng. (Copenhagen University), London, S.E.

12. Mr. William F. Laurie Thomas, Demerara, British Guiana.

13. Mr. J. Mason Blair, M.I.C.E., Engineer-in-Chief, Otago Harbour Board, Dunedin, New Zealand.

There are also two applications for studentship—namely :—

1. Mr. Charles Guy Burke Burdett, Mem. Junior Inst. Engineers, Westminster, S.W.

2. Mr. Walter Frederick Slate, Westminster, S.W.

This brings the total number of members up to 947.

CONTINUED DISCUSSION ON MR. THEOBALD'S PAPER

THE PRESIDENT (Mr. E. P. Wells) :—After I had adjourned the discussion on the paper on "Bills of Quantities for Reinforced Concrete Work," I was spoken to by one or two quantity surveyors as to the method that I employed in taking out quantities for reinforced concrete work, and whether I would also prepare a cartoon for this meeting. As you will see on the cartoons, I have given you a general outline of the methods that I employ throughout in taking out quantities for reinforced concrete.

These cartoons represent the sheets that go out to a contractor when he applies to me to get out designs and quantities for the work. You will see they are divided into four columns. Now, if it is a question of preparing proper bills of quantities in the usual way, the last column can be used for all labours, etc.

[The President then entered into the methods he employed in taking out the quantities in detail, and transferring the same to the paper, as shown by the cartoons.]

In conclusion, I strongly recommend that all items

Concrete.		Shutter.		Steel.		Analysis.					
BASE.	Cub. ft.	BASE.	Sq. yd.	BASE.	Lb.	BASE AND SPLAY.	Rate. s.	d.	£	s.	d.
4′ × 4′ × 6″	8	4/4′ × 6″	9)8	10/4′ 6″ at 0·64 lb. ...	29	Concrete, 19 cub. ft. ...	at 1	0	... 0	19	0
SPLAY.		SPLAY.				Shutter, 8/9 sq. yd.	at 1	9	... 0	1	7
4′ × 4′ × ⅓′ × 2′ ...	11	4/2′ 6″ × 2′ 1″ ...	9)20			Shutter to Splay, 2 2/9 sq. yd.	at 3	6	... 0	7	9
			2 2/9								
SHAFT.		SHAFT.		SHAFT.		SHAFT.					
20′ × 12′ × 12″ ...	20	4/20′ × 12″ ...	9)80	4/22′ at 4·17 lb. ...	367	Steel, 29 lb.	at 0	1¼	... 0	3	0
			9			Concrete, 20½ cub. ft. ...	at 1	3	... 1	5	8
SPLAY.		SPLAY.		LINKS.		Shutter, 9 sq. yd.	at 2	6	... 1	2	6
2/16″ × 6″ × 4½″ ...	½	2/2/16″ × 4½″ ...	2	24/3′ 2″ at 0·17 lb. ...	13	Shutter to Splay, 1¾ sq. ft....	at 0	9	.. 0	1	4
		2/1′ 9″ × 6″ ...	1¾	FERRULES.		Steel, 367 lb.	at 0	1¼	... 1	18	3
			3¾	4/9″ L.		Steel Links, 13 lb.	at 0	2½	... 0	2	9
						Ferrules, 9″ L for 1¼″ No. 4	at 0	6	... 0	2	0
									£6	3	3

Mr. Wells's Cartoon No. 1 (accompanied by Fig. 1 overleaf).

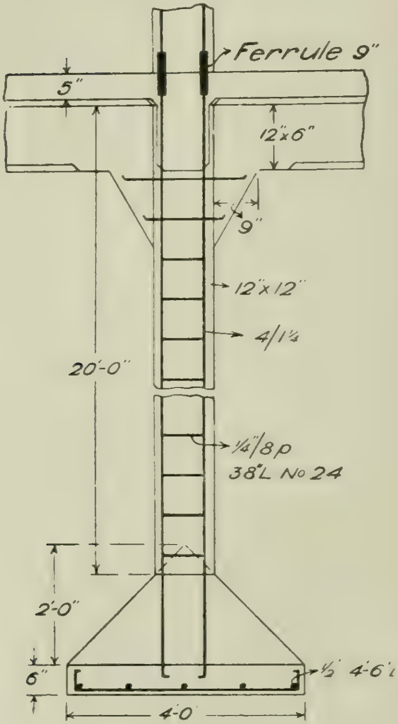

Ferrule 9"
5"
12"x6"
9"
12"x12"
4/1¼
20'-0"
¼"/8p
38"L No 24
2'-0"
6"
½" 4'-6"L
4'-0"

FIG. 1.

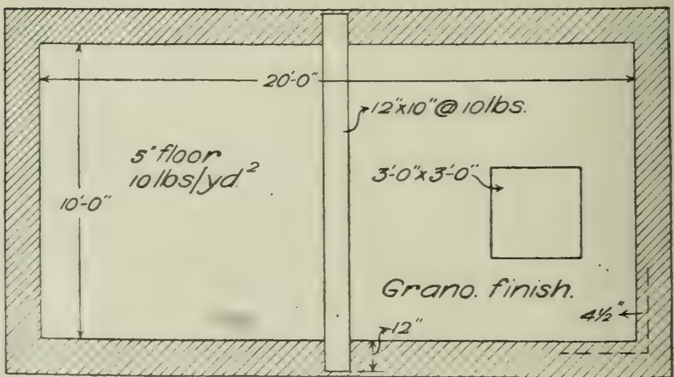

20'-0"
12"x10"@10lbs.
5"floor
10lbs/yd²
3'-0"x3'-0"
10'-0"
Grano. finish.
4½"
12"

FIG. 2.

Concrete.		Shutter.		Steel.		Analysis.	Rate. s. d.	£ s. d.
		5-inch Floor Slab.						
	Cub. ft.		Sq. ft.		Lb	Concrete, 90 cub. ft.... ...	at 1 0 ...	4 10 0
20′ 9″ × 10′ 9″ × 5″ — 3′ × 3′	90	19′ 2″ × 10′ — 3′ × 3′ ...	183	Concrete area at 10 lb. sq. yd. ...	240	Shutter, 21 sq. yd.	at 1 9 ...	1 16 9
		4/3′ × 5″	5			Steel, 240 lb.	at 0 $1\frac{1}{4}$ ...	1 5 0
	Sq. yd.		9)188			1″ Grano. extra only 24 sq. yd.	at 1 6 ...	1 16 0
Grano. concrete area	24		21	sq. yd.				
		Beam.				Concrete, 10 cub. ft. ...	at 1 2 ...	0 11 8
	Cub. ft.		Sq. ft.			Shutter, $3\frac{1}{9}$ sq. yd.	at 2 9 ...	0 8 7
12′ × 12″ × 10″ ...	10	10′ × 2′ 10″ ...	28	12′ at 10 lb.... ...	120	Steel, 120 lb.	at 0 $1\frac{1}{2}$ ...	0 15 0
			9)28					
			$3\frac{1}{9}$	sq. yd.				£11 3 0

Mr. Wells's Cartoon No. 2 (accompanied by Fig. 2 opposite).

in a bill of quantities should be numbered for easy reference, starting at 1, and so on to the end of the bill. It is far easier to refer to a number than to a certain line on a given page, and if alterations are required, it is quicker to say, "Alter item 150 to 50 cubic yards" than the usual long references.

MR. R. W. VAWDREY, B.A., Assoc.M.Inst.C.E. (Member of Council) :—I greatly regret not having been present to hear this paper read. I am connected with a specialist firm, and I must say, as far as I am concerned, I entirely agree with every single word that Mr. Theobald has said in his paper. The whole position of the question of designing reinforced concrete work in competition, as it exists at present, is most unsatisfactory, and to a very great extent I think that is due to the absence of the regularized method of dealing with the matter that obtains in nearly all other classes of construction.

But there are just a few points which Mr. Theobald makes in his paper that I should like to refer to in detail. To start with : he says on page 437 that when an architect decides to construct a building in reinforced concrete, he sends out sets of plans, etc., to one or more firms of specialists. If he confines himself to one firm of specialists, I do not think any of the unsatisfactory difficulties arise. The great difficulty, and the great amount of dissatisfaction which occurs in connection with the design of reinforced concrete work, is owing, in my opinion, to the fact that contractors are asked to tender, not upon one set of designs or one set of quantities, but on many such designs, all differing from each other. You get Jones and Smith tendering on one set of quantities and designs, and you get Brown and Robinson tendering on others, and so forth. It is that which introduces the chief difficulties that exist in the present system.

Mr. Theobald states, lower down on the same page, that the question of time tends to prevent the proper production of the quantities by a quantity surveyor, but surely that is an altogether inadequate reason. As he points out, no more time is required in the case of a reinforced concrete structure than in the case, say, of a steel structure, and therefore no more difficulty can occur in having the quantities properly prepared.

I am quite sure that everybody who has had any experience of the question will agree with Mr. Theobald that the specialists concerned—that is, those firms who make it their business to design in reinforced concrete —will welcome with open arms the introduction of the quantity surveyor, and I should like to point out that perhaps it is not quite so unusual a thing as Mr. Theobald thinks. In our own case, it is very frequently the case that our designs are submitted by the client for whom we have prepared them, either in competition or not, to a quantity surveyor for the proper quantities to be taken off. I do not think any of the concrete specialists have any objection whatever to that procedure. As is pointed out in the paper, that merely relieves them of a great deal of elaborate work for which they are not so well fitted as a quantity surveyor, and, of course, it relieves them also of some responsibility.

The point that Mr. Theobald makes on page 445, that he asks for a separation order, is, I think, a very good one. And this has been elaborated, of course, by the President in his remarks just now. The more the quantities for the different portions of the structure—the footings, columns, beams, etc.—are separated, the clearer and the cheaper it undoubtedly is ; in my experience, at any rate, I have found throughout that the greater the detail in which the quantities are given, the cheaper will be the prices obtained by the owner of the building.

I should like to go farther, and say that the separation of the quantities alone is not sufficient. The great point, in my opinion, as I tried to point out in a paper I read here on a somewhat similar subject a year or two ago, is that the question of the design and competitive tenders should be separate. It appears to me most disastrous that for some unknown reason the practice has become such as it is at present—namely, that the competitive designs which are necessary perhaps in some cases and competitive tenders which are more generally necessary should be merged together in one tender.

Then to deal with the discussion. The letter from Sir Henry Tanner merely bears out that point which I have just made. I naturally entirely agree with what

he says. On the question of delay he says a great delay occurs now, owing to the fact that after merely preliminary designs have been prepared, a tender will be accepted on them, and then subsequently before the work can be commenced all the detailed working drawings have to be prepared. Of course, they ought obviously to be prepared before the tender is accepted. That can only be done if a design is accepted, or a particular firm of designers is appointed before the work goes to tender.

I will just refer to one or two points made by Mr. Alban Scott. Of course, I entirely agree with his remark that it is unfair to the contractor if the various sizes of steel rods are not separated and specified. Clearly they should be, and of course they would be if a proper bill of quantities were taken out from the specialist's designs.

Mr. Alban Scott says that an architect is employed to look after his client's interests ; he cannot do this if he throws the responsibility of a portion of the work on to some other person. One would hardly suppose from that that Mr. Alban Scott had ever employed a specialist for his reinforced concrete work, yet I believe such to be the case.

Again, Mr. Alban Scott says that specialists do not guarantee their quantities. Of course, it may be the case that sometimes they do not ; on the other hand, sometimes they do, and it is surely very unfair to cast mud at random in that way. He says that "they do not as a rule employ men who have had training as quantity surveyors." Surely a firm of specialists may employ quantity surveyors as their assistants.

In conclusion, I should just like to call attention once more to the unsatisfactory nature of the present conditions. I think we all admit that the present method of tendering for reinforced concrete work is very unsatisfactory. The reason, as I have already said, is, in my opinion, the confusion of the question of designing in competition with that of tendering in competition. But I do wish to say that it is not the specialist firms who are to blame in the matter. If all architects would only realize that these firms exist as specialist firms of designers for the purpose of designing, things would be very much simplified. At present, in the great

majority of cases, architects or quantity surveyors acting for their clients almost invariably ask the specialist firms to submit tenders. Well, of course, that is absolutely incorrect. The specialist firm does not, except in a very, very few instances to my knowledge, submit tenders. The specialist firm is a firm whose existence is for the purpose of designing reinforced concrete work. If an architect wishes to erect a reinforced concrete structure, if it is essential for him to have competition, which I think it very seldom is, let him go to two or three firms, ask them to show what they can do, and to submit designs to him for his approval. Then let him accept the best, and let him submit that design which can then be worked out in full detail, to any number of contractors.

Let as many as he likes tender on the same design, but for goodness' sake let the architect get out of the habit of asking half a dozen specialist firms, or, more usually, all the specialist firms he can get hold of, to submit tenders. That means that specialist firms prepare the design themselves, ask the half-dozen or more contractors to tender upon it, and get the product of the number of specialists, and the large number of contractors as the total number of tenders sent in. The whole thing is, of course, absurd. Very often no one contractor is tendering on all the designs, and the best design is probably not tendered upon by the cheapest contractor. Consequently, so far from increasing the economy of the work, the owner of the building probably has to spend a great deal more than he otherwise would have done.

MR. FREDERIC HINGSTON, M. Quantity Surveyors' Assn., M.C.I. :—Mr. President and gentlemen, I am much obliged to you, sir, for asking me to join in this discussion, and also for the very clear statement you have given us of your suggestion for taking out quantities for reinforced concrete work. There are one or two points which I should like to mention, more with regard to the taking out of quantities for reinforced concrete work than for the employment of the specialist. I quite agree with some of the remarks of the last speaker, more especially with regard to employing one system and one firm for the work. But I am more concerned with the quantities than with the

specialist, and with regard to the concrete work itself, I think I understood Mr. Theobald to say that the concrete to the walls and the floors should be kept separate and the columns separate from either or both of the preceding. With this I agree, but I do not agree with the suggestion that the labours on small rods should be taken, unless the labours are very numerous.

As regards the centering, that should of course be taken at per square. I think that the beams should be given at per foot run, giving the sizes where possible. Of course, where the sizes differ very considerably they might be averaged, and I think those of one width might be averaged in the depth, and those of one depth might be averaged in the width. Shuttering to the beams should include the triangular fillets, and any labours upon them, and the labours to the superficial items taken separately. I also agree with him when he states that the openings in the shuttering to walls and floors should be deducted, and the extra labour for forming the openings should be numbered. As regards the larger steel work I think the labours thereon should be taken, and I agree with the last speaker that the whole of the steel work should be kept separate under its different sizes and the labours described.

There was one point I notice Mr. Theobald did not mention, and that was the finishing of the concrete. I take it that he would take that separately, and treat it very much as we do the plastering or similar finishing on the inside, and whatever facing there is on the outside, and whether of stone or brick should be described as facing to reinforced concrete work. Perhaps when you reply you will mention these points.

Mr. G. C. Workman, M.S.E. (Member of Council):—Mr. President and gentlemen, I very much regret that owing to illness I was not able to attend the interesting paper read by Mr. Theobald. I have carefully considered his views concerning this important question, and, speaking from the point of view of an engineering designer working under a patented system, I venture to make the following remarks :—

First of all, I am very pleased to see that Mr.

Theobald states quite clearly that he is making no reflection upon the quantities supplied by the engineers under the present system, and that his criticism is solely directed against the actual method of dealing with reinforced concrete work and not against its exponents. As a matter of fact, the reinforced concrete engineers are directed by circumstances over which they have very little control, and I feel perfectly sure that in many cases they would welcome the help of a quantity surveyor. Perhaps Mr. Theobald will be astonished to hear that I personally have endeavoured for many years to bring about a collaboration between the reinforced concrete designer, the architect, and the surveyor. Unfortunately, as mentioned before, we reinforced concrete designers are dependant upon the requirements of our clients, and competition prevents each individual firm of designers from attempting to dictate the proper course which the client ought to follow for the mutual benefit of all concerned. For instance, Mr. Theobald says that he is well aware that the time given for the preparation of a scheme and quantities does not admit of the employment of a quantity surveyor, and he suggests that the client must wait. The difficulty is that the client will not wait. The conclusion is obvious.

Mr. Theobald states that he believes that under the present régime the correctness of the quantities is not guaranteed. As a matter of fact, most of the firms of reinforced concrete designers working on similar lines to ours—I am now referring to the Coignet system—must guarantee the accuracy of the quantities, or at least of the unit quantities of concrete, steel, and centering for each element of the construction. It is evident that under these circumstances, taking into account the fact that the work must be done in many cases with extraordinary rapidity, there is a considerable amount of risk. The point is, assuming that surveyors would be willing to take out the quantities very rapidly of a large number of competitive schemes throughout the year, would they be prepared to take the financial responsibility for the accuracy of their quantities, and also to do this on the understanding that they would not receive any remuneration whatever for all those schemes which the firm of designers in col-

laboration with whom they were working were not successful in securing?

I am strongly of opinion that before anything practical can be done in the direction suggested by Mr. Theobald it will first be necessary that quantity surveyors should make an exhaustive study of the various systems which are at present continually in competition for works in reinforced concrete, and also that they should solve the question as to whether or not they are prepared to work in collaboration with the designers on the same speculative terms as the latter are compelled to adopt on account of the fact that they see no other alternative.

Mr. Theobald states that the methods of the modern quantity surveyors are the outcome of the knowledge of three or four generations who have had constant practice in this profession. Unfortunately, the quantities for reinforced concrete are quite different from anything to which surveyors are accustomed, so that the experience of all their ancestors will be of very little avail to them. In fact, I will go farther than this, and I would make so bold as to state positively that unless a quantity surveyor has a perfect knowledge of the particular system of reinforced concrete for which he has to take out quantities he is far less capable of doing this work properly and rapidly than the specialist engineer.

In conclusion, I am of opinion that the entire question concerning the employment of quantity surveyors in conjunction with reinforced concrete chiefly depends on whether or not the quantity surveyors are willing to take the same responsibilities and run the same risks as the specialist engineer, and I may add that personally I am quite willing to discuss this question with any surveyors who may wish to get better acquainted either with the system of reinforced concrete, which I represent, or concerning the subject in a general sense.

MR. MORITZ KAHN, M.C.I. :—Mr. President, I think Mr. Theobald has the honour of having presented one of the most interesting papers that have been read before this Institute, and although a good many kind things have already been said of him, I want to put in my little word in thanking him as well.

The paper under discussion only came before my attention this afternoon, and therefore I have not been able to give it that study which it merits, judging from the casual glance I cast over it.

I quite agree with most of the remarks I have read in Mr. Theobald's paper, and, like Mr. Theobald, I, too, hope that sooner or later, rather sooner than later, the quantity surveyor will take an active part in the measurements of reinforced concrete work. We delight in the designing of this class of construction, and a considerable amount of our cares would be removed if a fully qualified quantity surveyor were engaged by the architect to prepare our quantities.

I would call attention to the fact that the preparation of quantities for reinforced concrete work is probably more intricate than the preparation of other quantities. Each designer has his own method of detailing the work. These methods differ to a considerable extent, and standards which might be drawn up for one designer will not apply to another. The measuring of the concrete and steel in the respective items is a simple matter, and under ordinary circumstances the measuring of centering is a simple matter, but the ordinary circumstance is not the rule, with the result that, speaking offhandedly, it is a difficult matter to generalize a method of measuring quantities of centering. It seems to me that satisfactory results can be obtained by giving the contractor general measurements of the centering and submitting with your measurements such drawings as will enable him to understand the nature of the work he will be called upon to perform. After carefully studying such drawings, his experience ought to teach him how to price the centering. It is unfair that I should take up too much of the time of the members of this Institute in discussing a paper which has not been previously carefully studied by me, but I could not resist the temptation to say a few words, because the subject is such an interesting one to me.

Whilst I do not propose to submit a plea for the specialist, might I call the attention of the quantity surveyor to the fact that the present method adopted by the specialist is one which has been forced upon him by circumstances over which he has no control.

The specialist is not an enemy of the quantity surveyor, and, speaking for myself, I have often gone out of my way to insist upon a fully qualified quantity surveyor being called in to check either our original quantities or quantities of alterations in the final construction. I know for a fact that we specialists invite the assistance of the quantity surveyor whenever and wherever we can possibly find an opportunity to do so.

MR. PERCIVAL M. FRASER, A.R.I.B.A., M.C.I.: —Mr. President, I am in the position of one or two other speakers here; I was not at the last meeting, and I do hope I shall not traverse the same ground that other speakers traversed at the last meeting and this evening.

Coming straight to the paper, as a quantity surveyor I have to take exception to a few remarks that Mr. Theobald has made. I admire the style of his paper; it is a kind of literature we seldom get at this Institute. It is very breezy and racy and a real pleasure to read, and, as the advertisers say, once picked up you cannot lay it down till you have finished it.

On page 436 he says the apologia for a quantity surveyor preparing bills of quantities is that he gives a client the right of criticism. He says this is what the client likes. But I do not think there is one client in a thousand ever sees the bills of quantities; they are nasty-looking things for the layman. I do not think the client would peruse them with any great gratification, and I think Mr. Theobald might correct that impression, that the bills of quantities are simply to give the client that insight into the methods by which the building is carried out; they are for a much more serious use than that.

He says:—

> "At the present time, when an architect decides to construct a building of reinforced concrete, he sends a set of plans, sections, and elevations to one or possibly more firms of specialists, who then submit a scheme of construction under their respective systems, together with an approximate estimate of the cost."

Well, this is not the time to discuss first principles, but he is quite wrong there, I think. He saddles an architect with this somewhat undesirable method of carrying out a concrete building. I think he might, in mercy, have included engineers. Architects, I think, do not adopt this method ; it is a very iniquitous one. The concrete specialists themselves are beginning, I think, to freely state that they think the spirit of competition is very iniquitous, and I feel quite certain that I am speaking the truth when I say that every day shows a falling off in the desire of architects to have their concrete schemes prepared in a spirit of competition.

In regard to the specialist's approximate estimate, I do not think this is ever done. It may be done by special request, but surely it is not the common practice that Mr. Theobald states it is. One might almost imagine, from what he says, that specialists draw up their own specifications, supervise the building, and draw their own cheques on their own bank themselves, but their sphere is much more limited than he evidently thinks.

I must say that Mr. Theobald rather admits that he has little or no experience with regard to reinforced concrete buildings, and he seems to propound a large number of conundrums. I presume that we are invited to reply as far as possible to those questions.

With regard to the quantities supplied by specialists, this is absolutely universal, and I have never noticed any desire to shirk this responsibility on behalf of specialists. But Mr. Theobald has given an insight into the experience and skill necessary for a quantity surveyor. Now, the specialist's quantities consist of only three items—so many yards cube of concrete, so many squares or yards of centering, and so many tons of steel, and these are freely accepted by contractors. Why, I could never understand. And then, I am afraid that, say, 99 per cent. of specialists, if the quantities turn out all right, take the full credit for them ; if they turn out all wrong, they may accept the responsibility for the steel, but they are certain to say, " We know nothing about concrete and centering ; we are not quantity surveyors, we are specialist designers."

And he says :—

> "It must surely frequently happen, however, that in making the various details it is found necessary to alter the drawings from which the original quantities were prepared, and the latter are, consequently, inaccurate to that extent."

He further says :—

> "I believe that under the present régime their correctness is not guaranteed."

It is a form of acute inaccuracy to give one item of steel as the reinforcement for a building when that steel ranges from $\frac{3}{16}$ in. to $1\frac{1}{2}$ in. or 2 in. rods. That is a form of inaccuracy. It is misleading in the highest degree, and I think the specialist should absolutely refrain from giving quantities unless he is prepared to give them by employing, as Mr. Vawdrey suggests that some of them have on their staffs, quantity surveyors, trained up in a surveyor's office, or, failing that, they ought never to issue quantities. The system of employing quantity surveyors as members of their staffs is also, of course, very bad.

Mr. Theobald states that there are four forms of contract. I think he might also have included in those four the R.I.B.A. form, which is admitted by lawyers to be one of the finest forms of contract extant, applying to any business or trade ; and he might have stated, which is of vital interest, that this R.I.B.A. form is issued under two headings—one where quantities form part of the contract and one where they do not form part of the contract, and, as I say, this is the finest contract, I suppose, that exists on any business matter, and every member of this Institute would do well to get a copy. I am proud to think that this contract was drawn up by architects and not by engineers.

There is also another form of contract which he has omitted to mention, a very important one, largely used for alterations : prime cost plus profit. I am not to enter on the ethics of that now, because it is a highly complicated form, but in many cases it is ex-

ceedingly valuable, and I think it should have been mentioned in an authoritative paper of this sort.

The whole trend of this paper is, and, I think, quite rightly, a plea for the employment of quantity surveyors, but Mr. Theobald must not be too hopeful.

Mr. Theobald states that he thinks the engineers, and I presume by that he covers specialists, by the very reason of their profession are not in a position to take off the quantities for their work. Well, of course, with that I very heartily agree.

There is one very extraordinary thing he says with regard to the responsibility of quantity surveyors, as I think, with his great knowledge and experience of quantity surveying, he should be able to give this Institute some very interesting facts with regard to quantity surveyors' responsibilities ; but he does not seem quite sure of his ground. He says :—

> "If I am correct in saying that no responsibility is taken at the present time, the advantages are obvious, both to the building-owner and the contractor."

I am afraid we do not live in a Utopia of this sort. We cannot shelve our responsibilities ; we cannot say whether we will take responsibility or not. I am afraid other people say that for us, and a few words from Mr. Theobald with regard to the responsibility of quantity surveyors would be very valuable.

He says, "But until contractors have got used to our methods of net measurement. . . ." *Contractors*, not engineers. Surely contractors are used to net measurement. In London it is absolutely universal to measure net, with the exception of stonework. All other materials are measured net, and I do not fathom quite what he means when he says, "Until contractors have got used to our methods of net measurement."

THE PRESIDENT :—I will now ask Mr. Theobald to reply, but before doing so I wish to say that I have a long communication from Mr. A. C. Remnant. It will be published in the Proceedings ; it is too long to read. If there is anybody here who would like to make any written communications, the Secretary will be pleased to receive them. Before calling upon

Mr. Theobald, I think it is the desire of you all that we accord him a most hearty vote of thanks for the paper he has read to us on "Bills of Quantities for Reinforced Concrete." (Applause.)

Mr. JOHN M. THEOBALD, F.S.I., M.C.I. :—Mr. President and gentlemen, before I attempt to deal in detail with the criticism which has been passed on my paper, I wish to thank you for the generosity of that criticism. I am referring more particularly to those gentlemen who are engineers in reinforced concrete, as I confess I did not expect the welcome that I have received from them.

I feel that my paper has been read rather under a misapprehension. Its chief object was to justify the employment of the quantity surveyor, and I only touched very lightly upon the question of method of measurement.

The majority of the speakers have confined themselves to criticizing the suggestions in the latter part of the paper, and the advisability of the employment of a quantity surveyor in connection with reinforced concrete work has not been questioned.

The general consensus of opinion at the last meeting seemed to be that the form of contract numbered 4 in my paper, *i.e.*, the initial schedule and subsequent remeasurement, was the most practical solution of the problem.

As the time at my disposal is short I propose only to refer to those points which more or less directly challenge statements in my paper.

Dealing with the criticism of Mr. Alban Scott, I find I owe him an apology for one sentence which I used. I said "the acquaintance of my profession with yours is not of long standing." It was obvious that I had forgotten for the moment that the membership of the Concrete Institute comprised professions other than that of engineers in reinforced concrete. As a member of an outside profession myself I have no excuse for the oversight, and I apologize to him for the omission.

I quite agree with Mr. Bare's remark with reference to the question of steelwork in the schedule of quantities—assuming that No. 4 is the form of contract adopted. We must, of course, be furnished with

the weight of the various reinforcements by the engineer, as the detail drawings would not be ready, and there would be no other means of obtaining it.

With Mr. Kearn's criticism, and his suggestion of including all cuttings in centering, and of measuring beams per foot run (the latter suggestion being also supported by one gentleman whose name I have lost for the moment), I am afraid I cannot agree. The cutting and waste on the superficial centering of floors, etc., must be measured, and I cannot see any advantage in measuring beams per foot run, unless the depths and soffites are given in each case, *i.e.*, not averaged. Mr. Kearns is somewhat inconsistent, because he pleads for a shorter bill of quantities, while his suggestion of running the beams in various sections would tend to unduly lengthen it.

Mr. Davis's point as to the re-use of centering for concrete floors is one with which I am afraid quantity surveyors cannot deal. We must measure the entire superficial of centering, and leave it to the contractor to make such reduction in his price as he thinks necessary, after an inspection of the drawings.

Several speakers have dealt with the measurement of items which I have not mentioned. I said in my paper that I had only touched on the fringe of this question, and had I known the line the discussion was going to take, I should have gone much more fully into it.

I quite agree, for example, with Mr. Corderoy's contention that the method of measurement of every job will differ to a certain extent. In a paper of this length it has been impossible to do more than generalize, which is all that I have attempted to do. If I may presume to advise, I would say, "When in doubt, keep the item separate." You are then on the safe side!

I know I am only voicing the wishes of the meeting when I offer the President our hearty thanks for his lucid exposition of his method of taking out quantities, and also for the trouble he has taken to prepare the chart which is now on the wall. From a quantity surveyor's point of view his short lecture has been most interesting, and I feel he is much more competent to read a paper on quantities than I. I can only

say that, had his methods been adopted by other engineers in reinforced concrete, I should have had no justification whatever for reading my paper.

Mr. Workman asks me whether quantity surveyors would be prepared to take out quantities under the conditions he mentioned. I emphatically say, no! We have got to live, too! As I said in my paper, it is the system that is wrong, both from Mr. Workman's point of view and my own. I cordially agree with the remarks that have been made by several gentlemen with regard to the unfairness of architects obtaining tenders on four or five schemes simultaneously. By all means select *one*, have the quantities prepared, and a price obtained in competition.

Mr. Workman also criticized my allusion to the knowledge of our ancestors. I admit that this experience is not perhaps of direct assistance in connection with reinforced concrete, but it is not absolutely useless. They taught us *how* to measure, and it is comparatively easy to apply their principles to the measurement of any material that is placed on the market, but I have a lot to learn, Mr. Workman, and I admit it.

Mr. Workman :—I was only pulling your leg.

Mr. Theobald :—Well, you did it very successfully. I am sorry, in a way, that your cold prevented you from dealing with some of the criticism on similar lines!

With reference to Mr. Fraser's remarks on the question of clients seeing the bills of quantities, if he will read my paper again he will see I alluded to the "Variations," not the bills. Perhaps my experience has been an unfortunate one, but I have had a great number of clients who have gone very fully into the variations. I only hope it *is* an unusual one, and I congratulate Mr. Fraser as much as I commiserate myself. Mr. Fraser also accuses me of asking a lot of conundrums in the desire to get answers! If he will inform me how I can obtain information without asking for it, I shall be glad to take advantage of his advice on a future occasion.

I wrote the paper with the intention of provoking a discussion on the question, and, incidentally, learning

a lot. I *have* provoked the discussion, and I *have* learned a lot. I apologize to Mr. Fraser for having omitted the two forms of contract to which he refers. My sins of omission, I fear, are many, and I can only plead, as I carefully mentioned in my paper, that I spoke from my own experience.

Then dealing with the question of "nett" measurement, to which he, and I think it was Mr. Alban Scott, referred. The term "nett" as used by quantity surveyors is not legally correct, and must be very loosely interpreted. Their use of the term, however, is well understood by contractors, and can be taken to mean, for example, that the floor centering has been deducted for the beams, that the stanchions, if measured through to floor level, would be deducted from the concrete of the floor, and so on.

There is one more point which has been brought to my notice since writing this paper, and it is one with which I should have liked to deal at the time. I refer to the question of alterations in reinforced concrete from a quantity surveyor's point of view.

I was shown a bill of quantities a few days ago by a contractor in which there was an item for cutting away in a reinforced concrete floor to form a well hole for stairs (the size was given), including making good concrete and reinforcement, and taking all responsibility.

To my mind this method of dealing with an alteration is absolutely wrong, and I cannot too strongly condemn the practice of allowing an inexperienced contractor (I use the term "inexperienced" solely in this connection) to interfere with reinforced concrete. Include the cutting of the hole in your bill of quantities by all means, but you should also include a provisional amount to allow of the firm of specialists under whom the work was originally carried out making such alterations in the reinforcement as may be necessary. To place the responsibility on the builder is unfair both to the client and him. It should be placed upon the firm who could in all fairness be asked to accept it.

Before I sit down I wish to thank you, Sir, and, through you, the Council of the Concrete Institute, for allowing me to read this paper, for the generous

allowance of time you have given to the discussion, and also for the invitation you have extended to the members of my profession, which I can assure you, Sir, is a compliment very highly appreciated by them. Gentlemen, I thank you very much.

The following communication has been made in writing by MR. A. C. REMNANT, F.S.I. :—

Whatever methods are adopted for quantities of reinforced concrete consistency should hold a premier position. Reinforced concrete, as the lecturer remarks, has emerged from a healthy infancy and is now approaching the adolescent stage ; it remains, therefore, for the professions most concerned—viz., the engineer and quantity surveyor—to see that any methods of measurement adopted are uniformly agreed to and standardized, so that the steps of the erstwhile infant may terminate at an honourable point instead of tottering in diverse paths at the whim or fancy of individual practitioners ; therefore consistency is a most essential factor. I may allude to a large work I have in hand, where the original quantity surveyor in measuring concrete lintels makes no deduction whatever from brickwork where the lintels are 12 in. in height and under, but above that height brickwork is deducted for the void filled by the concrete lintel. In the building I have in mind are fairly thick walls, some ranging between 4 ft. and 5 ft. thick ; now, a 9-in. or 12.-in. lintel over an opening in such walls is not deducted, whereas a lintel 15 in. high in a $4\frac{1}{2}$-in. or 9-in. wall is deducted. In the bill of quantities the item appears as so many thousand feet cube of "breeze concrete in lintels and hoisting and fixing at various levels, including all requisite moulds." It will be seen from the description quoted that no information is given to tenderers as to whether the brickwork has been measured net—*i.e.*, voids filled by lintel deducted—or that no deductions have been taken. Such a course throws a great risk on the estimator, which would have been removed had the description of the lintels been supplemented by an explanatory note that for all lintels above 12 in. high brickwork was deducted. The lintels in question have been priced at the usual rates current where brickwork has been

deducted ; therefore the contractor enjoys the fortunate position where 9-in. or 12-in. lintels are in very thick walls of being paid for brickwork as well as concrete.

Well, coming to the latter pages of this paper, on page 443, I think any quantity surveyor at any time should be prepared to take the responsibility of his quantities without the slightly increased fee to compensate him for the risk. Why reward one for sobriety or for the elimination of risks which may take place in the hustling between the hours of 8 and 11 p.m., as outlined on page 438?

On page 444, as regards pricing, contractors with that unfathomable accuracy or speculation gained by experience are able to price anything, and the valuation of concrete, centering, and reinforcement is therefore comparatively simple and easy. I, however, side with Mr. Theobald in the desire for separation of the units comprising concrete construction. It is quite feasible to keep the concrete, centering, and metal separate for each floor ; it gives a tenderer the opportunity to place slightly higher rates for the higher levels if he desires, or he can lump his figures at one uniform rate throughout, as improved methods of hoisting have reduced the extra costs which used to be incurred in the olden days.

The crux of reinforced concrete is the centering—one might almost say its mainstay, even if of only a temporary nature—and I consider more detail should be given to the measurement of this. I agree with Mr. Theobald that openings should be deducted *in every case*, that centering should be described "as measured net, all openings deducted" ; we then know where we are. The centering to openings could be taken as numbered items or as *feet run* of "casing to sides of concrete so many inches thick in openings and to include for necessary struts and supports."

Mr. Theobald dismisses floor centering without discussion. Considerations should, however, be given to floor centering in small bays or panels where large numbers of beams are involved. The finesse of a concrete specialist who on a floor of perhaps 40 ft. by 60 ft. may have three or four varying thicknesses of floor concrete, due to the size of the bays, demands attention at the hands of the measurer as involving

a certain amount of additional labour and waste, although this is a matter more perhaps for adjustment in beam measurements.

Coming to these, Mr. Theobald suggests these should be measured by the foot super, and where 18-in. girt and under, at per foot runs. As surveyors we are used to descriptions of "casing to sides and soffits of beams," but I suggest that every estimator seeing such a description imagines that the sides of beams are, at any rate, equal, but when confronted by varying thicknesses of floor, such as I have just outlined, may when called on to do the work find a difference of $\frac{1}{2}$ in. between the sides, a difference which entails waste and labour out of proportion to the financial benefit derived in reducing the width to suit these varying conditions. Personally, I think, even if involving more items, it would be better to measure all beams by the foot-run, giving a sketch showing the width of soffit and actual heights of the sides. Estimators have then something definite to work on, and we as surveyors would not be confronted when adjusting variations with vexatious claims due to insufficient description.

As regards concrete, this might be separated as stated, but as regards beams only that portion *below* the decking should be so measured. I mention this as in my experience I have come across reinforced concrete measurements where beams are taken to top of decking, then the decking measured right over without deduction for the beams and to supplement all stanchions and columns measured from floor to floor, so that at the intersection of the head of a stanchion crossing of beams and decking one gets a glorious overlapping of material and consequent values. Therefore *net measurements* are strongly advocated, and let the work be valued on its own merits and not on its excesses.

As regards steel reinforcements, these being of small scantling are usually quite capable of being bent cold, and the weight descriptions should include a note to the effect that all bends and hooked ends are to be included. I think the whole question of reinforcement should be governed by weight measurements rather than numbered items for stirrups. Estimators know

by experience what this metal with its labour costs per cwt., but when broken into small items up goes the price and the estimator loses the job. The wiring of reinforcement members, being a comparatively small factor, might be included in the description. I think reinforcement might reasonably be divided and described as in floors, beams, and stanchions.

THE PRESIDENT :—I will now call upon Mr. Laurence Gadd to read his paper entitled "Action of Acids, Oils and Fats upon Concrete."

MR. W. LAURENCE GADD, F.I.C., M.C.I. :—Mr. President and gentlemen, in addressing this short paper to the Concrete Institute, I am conscious that it is a very scrappy contribution, but the choice of the subject was not mine. It was suggested to me by the Secretary some little time ago—at any rate, I did not question his authority, and, unfortunately, I have not had the time to go into a subject like this as thoroughly as it ought to be gone into. I had therefore to fall back very largely upon work which I had done at various times previously for my own information. I therefore want to say I do not present this paper as in any way a comprehensive treatment of the subject, but as offering a small, a very small, contribution to the study of the material which this Institute is so greatly interested in.

MR. GADD then read his paper—

ACTION OF ACIDS, OILS AND FATS UPON CONCRETE

With regard to the mineral acids—*e.g.*, hydrochloric, nitric, and sulphuric acids—there is little to be said. Neither cement nor concrete will withstand the action of these acids, which decompose and dissolve the constituents of cement, even in dilute solution. Even a weak acid, like carbonic acid, has a distinct action upon cement, which, suspended in water, can be practically entirely carbonated by passing a current of carbon dioxide into it.

The action of organic acids, such as lactic and butyric acids, formed by the fermentation of milk or butter; tannic acid, occurring in tanning liquors; tartaric and citric acids, and acetic acid in vinegar or stale beer, is not so marked; but it is very probable that the whole of the series of higher fatty acids will be detrimental to concrete.

In most cases the action of the organic acids is confined to a combination with the calcium hydrate liberated when cement or concrete is gauged with water; but, as the organic lime-salt formed has no cohesive strength, the concrete must be deteriorated to a greater or less extent, depending upon the quantity of the acid and on its combining weight.

The tendency of organic acids to combine with carbonate of lime is much less than with hydrate of lime, and it follows that an acid which would be dangerous in contact with green concrete might be perfectly harmless in contact with old or indurated concrete. Thus, stale beer has a distinctly detrimental action upon new work, but once the concrete has indurated by exposure to air for some time, the acid of sour beer has little action upon it.

Fresh beer has, itself, a weakening action on green concrete, as the following experimental results show; but the deterioration in this case is due to the sugar and other organic constituents of the beer, and not to the action of beer acids.

TABLE A.

Tensile Strength (lbs. per square inch).

	Neat.			Sand (3 : 1).	
	3 Days.	7 Days.	28 Days.	7 Days.	28 Days.
Kept in water	630	765	1,020	340	425
	620	730	960		
	625	747	990		
	Plunge pat—Sound.				
Kept in beer	620	710	810	300	360
	560	675	750		
	590	692	780		
	Plunge pat—Failed.				

The test pieces were gauged with water in the usual way, and after twenty-four hours in moist air were immersed in water and beer respectively until due for breaking.

One of the commonest forms of acid action to which building material is subjected is that of sulphuric acid, derived by oxidation from the sulphurous gases present in the atmosphere of large towns. This is noticeable on Portland stone, of which many buildings in London are constructed. It appears to be less marked on concrete buildings, possibly for the reason that the surface pores of concrete become closed with a deposit of calcium sulphate, which affords protection from further action of the acid.

Lactic acid is produced by the fermentation of milk, brought about by the micro-organism *Bacterium lactis*, and is a possible acid to come in contact with concrete structures in farm buildings. The action of this acid is confined to combination with calcium hydrate, forming calcium lactate ($Ca(C_3H_5O_3)_2 + 5H_2O$). This salt is soluble in water, and in wet situations would be readily leached out of concrete in which it were formed, so that the deleterious effect of lactic acid would consist in the gradual removal of the lime hydrate, which plays an important part in the induration of concrete. For practical purposes, it is probable that this action would be very small.

The following tests show the effect of prolonged immersion in a solution of lactic acid, prepared by fermenting milk, and removing the curd :—

TABLE B.

Mortar 4 : 1 (ordinary building sand).

Test pieces 1 day in air, 27 days and 3 months in the whey and in water respectively.

	Tensile Strength.		Crushing Strength.	
	28 Days.	3 Months.	28 Days.	3 Months.
In whey	430	470	4,700	6,700
	440	470	4,900	6,000
	435	470	4,800	6,350
In water	400	495	4,600	6,800
	410	480	4,750	7,000
	405	487	4,675	6,900

This is, of course, a much more drastic test than would be at all likely to occur in practice, but the results do not disclose any marked deterioration caused by the lactic acid.

Concrete vats would appear to be suitable for tanning operations, and the possible action of tannic acid becomes of importance. This acid, of which gallotannic acid ($C_{14}H_{10}O_9$) may be taken as a type, is again an organic acid which combines with calcium hydrate to form calcium tannate, but as the combining weight of tannic acid is high—sixteen parts by weight combining with only one part of calcium—the probable action is not very serious.

The following tests were carried out in order to ascertain the effect of gauging with a solution of tannic acid (two grams per litre) and, for comparison, test pieces of the same cement were made in the usual way, gauging with water only :—

TABLE C.

TENSILE STRENGTH.

Neat.					Sand (4 : 1).				
7 Days.	1 Mon.	2 Mons.	3 Mons.	6 Mons.	7 Days.	1 Mon.	2 Mons.	3 Mons.	6 Mons.
Gauged with Tannic Acid.									
820	865	960	880	870	300	345	375	375	400
795	820	920	875	860	290	325	355	360	360
790	845	—	—	—	290	325	—	—	—
801	843	940	877	865	293	331	365	367	380
Gauged with Water.									
845	940	930	940	965	335	345	390	415	430
800	920	920	920	950	315	340	385	390	435
830	905	—	—	—	310	340	—	—	—
825	921	925	930	957	320	341	387	402	432

CRUSHING STRENGTH.

Gauged with Tannic Acid.									
7,000	9,000	11,600	11,300	12,700	3,000	4,600	5,700	5,800	6,900
7,100	9,300	10,950	11,200	12,650	3,200	4,450	5,500	6,050	6,650
7,000	9,550	—	—	—	3,000	4,550	—	—	—
7,033	9,266	11,275	11,250	12,675	3,066	4,533	5,600	5,925	6,775
Gauged with Water.									
7,600	9,750	11,000	12,300	14,600	3,400	4,900	5,250	6,800	7,150
7,750	10,000	11,700	11,850	13,900	3,350	5,150	5,000	6,500	7,500
8,150	9,900	—	—	—	3,350	4,800	—	—	—
7,833	9,883	11,350	12,075	14,250	3,366	4,950	5,175	6,650	7,325

One specimen for each period was removed from the water after twenty-six days, and kept for the remainder of the time in air.

These gave the following results :—

TABLE D.

TENSILE STRENGTH.

Neat. 2 Months.	3 Months.	6 Months.	Sand. 2 Months.	3 Months.	6 Months.
Gauged with Tannic Acid.					
880	815	815	380	450	460
Gauged with Water.					
910	885	890	420	515	510

CRUSHING STRENGTH.

Neat. 2 Months.	3 Months.	6 Months.	Sand. 2 Months.	3 Months.	6 Months.
Gauged with Tannic Acid.					
10,600	11,050	12,150	5,600	6,350	6,700
Gauged with Water.					
10,750	11,300	12,850	5,350	6,700	6,850

It will be seen from the above that the test pieces gauged with tannic acid solution gave lower tensile and crushing strains, but the difference is not sufficient to mark any great deterioration.

OILS AND FATS.

Proposals have of late been made, particularly on the other side of the Atlantic, to incorporate a certain small amount of oil or fat with concrete, with the object of giving the same dustless, waterproof, and other qualities. What we might almost call the natural instinct of the concrete worker has, however, always led him to avoid oil or grease as far as possible, and he has been right. Whether we accept the crystallisation theory, or the colloidal theory of the setting of cement, the presence of oily matters must interfere with the process of setting, even assuming that the oil has no chemical action with the constituents of the cement. Furthermore, oil does not readily mix with water and has a tendency to collect in globules, which, however small, are a source of weakness to the concrete.

Many oils and fats react chemically with the cement

constituents, and in this class must be placed the whole of the oils and fats of animal or vegetable origin.

These substances consist of the glycerides of various fatty acids, such as stearic, palmitic, and oleic acids, although the acids may be present in the free state, as, for instance, in palm oil, which may contain from 50 per cent. to 80 per cent. of free acids calculated as palmitic acid.

The glycerides of the fatty acids, which constitute the neutral oils and fats of animal or vegetable origin, are readily decomposed, or saponified, by certain metals and metallic salts, and by all alkalies, including calcium hydrate, which we know is a constant product in cement or concrete which has been gauged with water. The result of this saponification is the decomposition of the oil with the formation of a metallic or alkaline salt or soap, and the liberation of glycerin.

Thus, tallow is saponified by calcium hydrate, according to the following equation :—

$$2C_3H_5(C_{18}H_{35}O_2)_3 + 3Ca(OH)_2 = 2C_3H_5(OH)_3 + 3Ca(C_{18}H_{35}O_2)_2$$

Tristearin (tallow) + calcium hydrate = glycerin + calcium stearate (lime soap).

Calcium stearate is a whitish, friable material, insoluble in, and immiscible with water ; whilst the lime soaps of other fatty acids commonly occurring in oils and fats, are slimy and sticky substances which, although water repellents, do not, so far as my experiments show, render concrete less permeable to water, and decidedly reduce the tensile and crushing strength.

By this process of saponification, which takes place rapidly under the influence of heat and more slowly in the cold, cement or concrete will certainly be injured by the admixture of any animal or vegetable oil or fat ; and if the concrete be green or new, there is some liability of damage being done to it by mere contact, such as might occur from constant drippings of oil upon it.

Calcium carbonate has not the power to saponify neutral oils or fats, so that oil in contact with indurated concrete, in which the calcium hydrate has been largely converted into carbonate, would have little deleterious action.

Mineral oils and greases, which are hydrocarbons, are of a different constitution from that of the animal and vegetable oils, and are incapable of saponification. They have, therefore, no injurious action from this particular cause, although they weaken the strength of concrete for physical or mechanical reasons.

This is experimentally confirmed by the following series of tests on sand mortar 3 : 1, in which various oils and fats were incorporated to the extent of $\frac{1}{10}$ of the weight of cement used.

TABLE E.

CRUSHING STRENGTH.

Oil added—	7 Days.	1 Month.	3 Months.	6 Months.	12 Months.
None	4,000	6,200	7,000	8,300	8,750
(kept in water)	4,200	5,700	7,350	8,850	8,800
	4,050	5,450	7,200	8,600	8,900
	4,083	5,783	7,183	8,583	8,816
(kept in air)	4,200	5,500	6,550	6,850	7,100
	4,400	4,700	6,200	6,700	7,150
	3,900	4,900	6,900	7,000	7,600
	4,166	5,033	6,550	6,850	7,283
Vaseline	2,700	4,250	3,550	4,800	5,250
(kept in water)	2,900	3,850	3,950	4,550	4,800
	2,750	3,500	4,100	4,400	5,100
	2,783	3,866	3,866	4,583	5,050
(kept in air) ...	3,150	2,150	4,400	4,600	4,600
	3,300	2,200	4,400	4,550	4,550
	3,300	1,900	4,400	4,450	4,750
	3,250	2,083	4,400	4,533	4,650
Cylinder oil	3,600	4,800	5,000	6,200	5,400
(kept in water)	3,550	4,350	4,600	5,900	5,000
	3,200	4,200	4,500	5,600	5,250
	3,450	4,450	4,700	5,900	5,216
(kept in air)	2,100	2,900	4,600	4,600	4,300
	2,600	2,600	4,300	4,200	4,700
	2,650	2,650	4,150	4,400	4,500
	2,450	2,716	4,350	4,400	4,500

TABLE E—*continued.*

CRUSHING STRENGTH.

Oil added—	7 Days.	1 Month.	3 Months.	6 Months.	12 Months.
Lard	1,150	1,950	2,900	3,500	3,400
(kept in water)	1,300	1,400	2,900	3,000	3,600
	1,300	1,700	2,500	3,200	3,200
	1,250	1,683	2,766	3,233	3,400
(kept in air)	1,000	1,700	2,000	2,700	2,200
	1,000	1,550	2,100	2,700	2,350
	1,250	1,700	1,900	2,500	2,600
	1,083	1,650	2,000	2,633	2,383
Cotton-seed oil ...	950	1,700	2,300	3,500	3,900
(kept in water)	900	1,900	2,400	3,800	3,800
	950	1,750	2,700	3,500	3,450
	933	1,783	2,466	3,600	3,716
(kept in air)	1,000	1,150	1,000	1,900	1,600
	900	1,050	1,200	1,700	2,000
	750	1,100	1,200	1,500	1,850
	833	1,100	1,133	1,700	1,816
Colza oil	100	0	0	500	700
(kept in water)	100	0	0	500	800
	100	0	0	550	700
	100	0	0	516	733
(kept in air)	200	0	0	500	600
	200	0	0	400	0
	200	0	0	400	0
	200	0	0	433	200

In the above table the first two oils are mineral, the third is animal, and the last two are vegetable oils.

The results show that the vegetable and saponifiable oils cotton-seed and colza are absolutely destructive to concrete, and that the mineral oils, which are not saponifiable, reduce the strength very materially when mixed in small proportion with the mortar. It will be noticed that the strength at twelve months is less than at six months in the cases of cylinder oil (mineral), lard (animal), and colza oil (vegetable).

When testing samples of cement for tensile strength,

which is commonly done now by users, I have observed that many operators use colza oil for the purpose of greasing the briquette moulds. The film of oil which remains, or should remain, on the moulds is, of course, very thin, but colza oil cannot be considered a suitable oil for the purpose, seeing that it has so great an action upon cement. Briquette moulds should be oiled with mineral oil, or a mixture of heavy mineral oil and paraffin.

In order to test the waterproofing qualities of oil-mixed concrete, flat slabs of similar mixtures to the above were made in a standard manner, and, after twenty-eight days, were submitted to percolation tests by subjecting them to a water pressure of 50 lbs. per sq. in., in such manner that the water forced through the slabs could be collected and measured. The following table sets forth the results obtained :—

TABLE F.

Slabs kept 28 days in water before testing.
Size of slabs—10 × 10 × 3 in.
Area subjected to water pressure—16 sq. in.

WATER PERCOLATED THROUGH THE SLABS.

Oil added.		Litres per Hour.
None (cement only)	(1)	4·7
	(2)	17·7
Vaseline	(1)	1340·0
	(2)	340·0
Cylinder oil	(1)	695·0
	(2)	260·0
Lard	(1)	Slab broke
	(2)	,,
Cotton-seed oil	(1)	,,
	(2)	41·2
Colza oil	(1)	Slab broke
	(2)	,,

It is to be noted that these slabs were not intended to be made absolutely watertight, the object being to obtain a comparison. Leighton Buzzard sand was therefore used, and the results show that under identical conditions sand mortar without any addition of oil was more watertight than with any of the oils or fats tried. The addition of lard, colza, and cotton-seed oils to the extent of less than 2·5 per cent. on the weight of the concrete prevented the slabs from setting properly

even after twenty-eight days, and they were unable to withstand the water pressure placed upon them.

MR. R. W. VAWDREY, B.A., Assoc.M.Inst.C.E. (Member of Council):—Was that $2\frac{1}{2}$ per cent. of the water?

MR. GADD:—No; it was $2\frac{1}{2}$ per cent. of the cement used; one-tenth of the dry cement.

In order to test the effect of oils upon concrete gauged with water in the usual way a number of briquettes was prepared, consisting of four parts of

TABLE G.

	Tensile Strength.				Crushing Strength.			
Immersed in—	1 Mon.	3 Mons.	6 Mons.	12 Mons.	1 Mon.	3 Mons.	6 Mons.	12 Mons.
Water	445	540	560	605	4,600	4,900	6,650	7,400
	445	510	530	595	4,750	5,800	6,250	7,850
	445	525	545	600	4,675	5,350	6,450	7,625
Paraffin	480	516	550	620	4,500	4,650	6,500	7,150
	420	565	510	585	4,500	5,200	6,200	7,400
	450	540	530	602	4,500	4,925	6,350	7,275
Turpentine ...	435	500	520	610	4,350	5,200	5,250	5,900
	410	450	485	575	4,500	5,400	5,500	5,800
	422	475	502	592	4,425	5,300	5,375	5,850
Heavy mineral oil	450	530	570	545	4,400	6,300	6,500	5,850
	465	550	565	510	4,800	6,700	6,500	5,700
	457	540	567	527	4,600	6,500	6,500	5,775
Cotton-seed oil ...	0	0	0	0	2,350	800	800	1,900
	0	0	0	0	1,200	1,700	1,000	1,650
	0	0	0	0	1,775	1,250	900	1,775

ordinary building sand to one part of cement; and after twenty-four hours in moist air these were immersed in various oils for periods of one, three, six, and twelve months, at which dates the tensile and crushing strengths were ascertained.

A further series of similar test pieces was prepared, but in this case the briquettes and cubes were allowed to mature in air for twenty-eight days before they were immersed in the oils.

TABLE H.

Immersed in—	Tensile Strength. 1 Mon.	3 Mons.	6 Mons.	12 Mons.	Crushing Strength. 1 Mon.	3 Mons.	6 Mons.	12 Mons.
Water	485	515	565	570	5,400	6,150	6,900	7,000
	450	500	530	560	5,650	6,700	6,600	7,300
	467	507	547	565	5,525	6,425	6,750	7,150
Paraffin	400	425	465	470	4,200	4,850	4,850	5,400
	400	380	460	425	4,650	4,350	5,150	5,900
	400	402	462	447	4,425	4,600	5,000	5,650
Turpentine ...	400	345	320	430	4,000	3,900	4,500	4,500
	400	340	315	425	4,250	3,550	4,550	4,700
	400	342	317	427	4,125	3,725	4,525	4,600
Heavy mineral oil	460	410	430	450	4,150	5,500	4,500	4,800
	440	390	425	450	4,500	5,400	4,200	5,250
	450	400	427	450	4,325	5,450	4,350	5,025
Cotton-seed oil ...	75	0	0	0	2,700	0	0	0
	50	0	0	0	2,650	0	0	0
	62	0	0	0	2,675	0	0	0

These tests again bring out the destructive action of saponifiable vegetable oil, the test pieces immersed in cotton-seed oil being reduced to mud in less than three months; and although the mineral oils and turpentine had much less marked effects, they nevertheless materially reduced the strength of the concrete immersed in them.

The broken briquettes, which had been immersed in oils for twelve months, were freed from the sand,

TABLE I.

Briquettes immersed in :	A. Paraffin. Per Cent.	B. Turpentine. Per Cent.	C. Cylinder Oil. Per Cent.	D. Cotton-seed Oil. Per Cent.	E. Cotton-seed Oil Per Cent.
Silica	20·74	18·79	20·12	16·08	13·59
Alumina and iron oxide	9·46	8·24	9·00	6·40	4·91
Lime	54·29	49·78	53·31	40·48	32·31
Magnesia	1·28	1·27	1·48	·96	·82
Sulphuric anhyd....	1·32	1·32	1·30	1·07	·97
Combined oil Combined water	12·18	6·50 12·50	12·62	18·30 15·75	31·76 14·19
Potash and soda ...	·73	1·60	2·17	·96	1·45
	100·00	100·00	100·00	100·00	100·00

as far as possible, by sifting, and from adhering oil by repeated extractions with ether, and then submitted to chemical analysis. Eliminating the traces of sand still remaining in the samples, the results were as given in Table I on preceding page.

Samples A, B, C, D had been one month in air and twelve months in oil. Sample E was kept only one day in air before immersion for twelve months in oil.

The results show that concrete in contact with certain oils suffers chemical change by the combination of the liberated calcium hydrate with the fatty acids of the oil, as much as 32 per cent. of oil being combined in a period of twelve months, when green concrete is immersed in cotton-seed oil.

This amount of oil in combination as calcium oleate and stearate is quite sufficient to account for the disintegration of the concrete.

It will be observed that in the parallel cases of briquettes immersed in cotton-seed oil after one month's induration, and after one day only in air respectively, the action of the oil is much less marked in the former than in the latter, due to the fact, as mentioned earlier in this paper, that fatty acids do not react with calcium carbonate.

The conclusions I draw from theoretical and experimental data are :—

1. That the addition of oil or fat, of any kind, to concrete results in a weakening of the strength.

2. That animal and vegetable oils have a direct action on green concrete, and in time will bring about its destruction.

3. That indurated concrete is less liable to be attacked by oils and fats.

4. That oil-mixed concrete is not rendered more waterproof. The least permeable concrete is, in my opinion, a dense mortar in which the aggregate is properly graded to fill the voids.

DISCUSSION.

THE PRESIDENT :—I think we must thank Mr. Gadd for his interesting paper. One thing he had proved is this : that the addition of any extraneous

matter to Portland cement does not improve its strength. It is well known, and I am glad that he has proved it by experiment, that where acids and oils generating acid come into contact with concrete, then destruction is bound to take place sooner or later. In amplification of his paper, I wish to give some experiments I had made for me some six or seven years ago as to the action of creosote upon concrete. I was designing a tank to contain creosote, and I wanted to find out what the action of creosote would be upon concrete which had been kept in water for six months and then immersed in creosote. The concrete was composed of 5 to 1, 3 to 1 sand, and neat cement, and in every instance where it had been kept in creosote for eighteen months the strength was higher than when it was kept in air. In the case of the neat-cement cubes, after eighteen months' immersion the crushing amounted to 1,363 tons a square foot, or 9·46 tons a square inch. It had been kept under normal conditions—that is to say, in temperatures ranging from 35° to 60° Fahr., and during the whole eighteen months for the neat-cement tests the creosote had not permeated it at all ; and for the concrete cubes it had only indurated to about one-eighth of an inch, except where one sample was made with a very soft and porous stone ; then it went right through. But when the same neat cubes were placed in a chamber where the creosote was heated to 120°, in less than fourteen days it went clean through the specimens.

I will now call upon Mr. Butler to open the discussion.

Mr. D. B. BUTLER, Assoc.M.Inst.C.E., F.C.S. (Member of Council) :—I wish to thank Mr. Gadd for his very able contribution to our proceedings. Only those who have had occasion to undertake research of this kind can realize the immense amount of work involved. Mr. Gadd was modest enough to say at the commencement of the paper that he had only touched the outside of the question, but I can quite sympathize with him for the amount of work he must have undertaken to get all these data together.

It is a little peculiar that the very first substance or liquid which Mr. Gadd mentions is beer. Well, gentle-

men, I think as a rule the effect of beer on concrete is indirect, very indirect, and it has been known to have very bad effects. But I would like to ask Mr. Gadd, referring to his beer tests, as to what effect the beer had on the setting of the cement. I see he mentions that the plunge pat in water was sound, whereas the plunge pat in beer failed. Mr. Gadd, in most of his experiments, only gives the average of two cubes or briquettes at each date. I quite appreciate the immense amount of work it would have involved to give the usual average of five or six, but, referring to Table B and the result of the three months' crushing tests, if he had happened to have taken only one cube instead of two he might conceivably have got 6,700 in the whey and 6,800 in the water, or practically the same. This shows the necessity in all such experiments of taking a fair average ; two is not enough.

With regard to Table C, where comparative tests are given with tannic acid and water, in this experiment the test-pieces in each case were mixed with a solution of tannic acid. That seems to me to be scarcely so practical as it would have been if the test-pieces had been made with water in the ordinary way and immersed in a solution of tannic acid. We do not as a rule, I believe, gauge our briquettes or concrete with tannic acid, although, as Mr. Gadd suggests, the concrete is sometimes subjected to the liquids resulting from tanning.

On page 507, I quite agree with Mr. Gadd's remark where he refers to what he calls the natural instinct of concrete-workers in avoiding oil or grease of any kind. We know that before moulding briquettes or other test-pieces we always oil our moulds slightly. But do we oil them to make the cement stick to them or otherwise? This seems to me a very fair answer to those who advocate mixing oil of any kind with cement.

In Table E, on page 509, he gives the results of various vaselines and oils mixed with cement. I should just like to ask Mr. Gadd how, seeing that water will not mix with oil properly, he managed to incorporate those small proportions of vaseline and oil with the concrete. It would be of interest to know his *modus operandi*.

Referring to the same Table E and the last series relating to colza-oil, it is a little curious that the seven days' tests show a small but distinct crushing strength, while at one month and three months they show no strength at all ; then they harden again, and at six months and twelve months they have gained still further strength. It is very curious, and I should like to know if Mr. Gadd can explain it. Why a material developing strength at seven days should show nothing at all at one month and three months, and then again develop strength at six and twelve months, seems to me a little inexplicable.

I am still asking for information, Mr. Gadd. It would be interesting to have some particulars of the method in which you carried out the percolation tests. Some twenty-five years ago I helped my old chief, the late Henry Faija, in his experiments with regard to the forced percolation of sea-water through concrete, and in that case we used $1\frac{1}{2}$-in. briquettes, composed of 3 to 1 sand. We fixed a brass clamp top and bottom of the briquette, to which was attached a screw nozzle leading to a pipe, which was attached to a water tank 15 ft. above, so that in that way we got a 15-ft. head of water forcing through the briquette. We found that after a time the percolation ceased entirely, both with sea water and fresh water, owing to the blocking up of the pores.

Referring to Table G, where Mr. Gadd immerses his test-pieces in various oils compared with water, it seems rather drastic treatment to immerse a briquette in oil or turpentine. But a rather curious result there is that the tensile strength in the cotton-seed oil is absolutely nil in each case, whereas the crushing strength varies from 900 lb. to 1,700 lb. at various dates. The same kind of irregularity occurs in Table H, where the cotton-seed oil at one month gives only an average of 62 lb. tensile, but an average of 2,675 crushing. Now, as Mr. Gadd is aware, the usual ratio between tensile and crushing stresses is somewhere about 1 to 10—that is, the crushing is about ten times the tension. It is a little curious that in this case it should be only about 1 to 40, roughly speaking.

Re Table F, I should like to ask Mr. Gadd if, in

addition to the analyses of the briquettes immersed in the various kinds of oil, in which he gives the combined oil and combined water, he also analysed a briquette immersed in water only, so as to determine the amount of combined water in it ; that would be useful information, compared with the combined water in the other test-pieces.

MR. A. ALBAN H. SCOTT, M.S.A. (Member of Council) :—I have very great pleasure in seconding this hearty vote of thanks to Mr. Gadd for his most interesting paper. I cannot enter into it from the chemist's point of view, but I know from the practical point of view it will be extremely useful to us.

There is rather a curious coincidence in Table E. The crushing strength of the cement at seven days is about 4,000, and at twelve months it is almost all the way through just double that strength. It is extremely interesting because it is fairly consistent, with the exception of about two in the Table.

With regard to the percolation of water through the cement, we were architects for a very large reinforced concrete tank about eighteen months ago, and it had very slight leakages at first, but all those pores are now filled up, and I believe that is the usual experience with concrete subjected to a head of water, that it does, if properly made, become eventually more watertight.

MR. BUTLER :—It depends on the filtering properties as to how close the concrete is. If the concrete is too porous, of course it will go on.

MR. ALBAN SCOTT :—Assuming, of course, it is fair average concrete for that class of work. But an interesting thing which our client did in that case was this : he threw oatmeal into the water, and whether it was the oatmeal that gradually flowed to the point of leakage that did actually fill them up, or whether it was due to the action of the cement is questionable. Mr. Butler thinks probably it would be the oatmeal ; it is quite a good thing.

THE PRESIDENT :—When a boiler leaks, people put in oatmeal or sawdust.

MR. ALBAN SCOTT :—Well, it is quite good in

concrete tanks I think. Mr. Butler mentioned a question of the number of cubes tested. We find that in our test-cubes we cannot rely on anything less than five to get a good average. Not that I am in any way criticizing the small number given here, because the data given is most valuable, and must have taken up a very considerable amount of time.

Taking Table F for vaseline, there you get No. (1) 1340·0, No. (2) 340·0. With those two you cannot get a proper average. We find, in our experience that five is a proper number; we make six tubes and keep one for further tests or examination if necessary.

MR. R. W. VAWDREY, B.A., Assoc.M.Inst.C.E. (Member of Council):—I should just like to ask the author a question. To what extent does he think that the weakening of the concrete, either in tension or compression, is due to the actual diminution of the size of the concrete? I take it that in some cases at any rate, where the action on some of his briquettes was very marked, as in the case of colza-oil, there was an actual diminution in the size of the block. Apart from that, however, there must often be a considerable proportion of the interior of the block or briquette that is quite unaffected. It would be rather interesting to know, in conjunction with the results which he obtained, what area of the cube or briquette was actually affected by the oil. In some cases it need not be necessarily affected throughout its depth.

Also, as unfortunately I am not a chemist, I should be glad if the author would explain exactly what is meant by saponification of the oil. It appears that any oil which is subject to that process is very deleterious, whereas oil which is not capable of undergoing that process does not affect concrete. What really is the cause of that?

I should also like to add my word to the remarks of the other speakers in thanking the author for his paper. I think it is impossible to conceive a paper which is more valuable to the users of concrete than that which he has just read.

MR. PERCIVAL M. FRASER, A.R.I.B.A., M.C.I.: —I would like to ask one question, Mr. President. I

am afraid I am not an expert in oils. Are any of the oils stated here volatile oils?

MR. GADD :—Oh, no, not volatile, except in so far as paraffin or turpentine are volatile.

MR. FRASER :—I was going to say that both petrol and reinforced concrete are so much to the fore in these days that a little experiment in connection with the two might be quite interesting.

In one or two of the tables there are blanks standing in place of tests. Are we to assume that the cube or pat, whatever it might be, failed utterly at that point?

MR. GADD :—Will you tell me what table that is?

MR. FRASER :—Well, Table C and Table E, Table C particularly.

MR. GADD :—May I explain that at once, Mr. President? If you notice, I say at the top of page 507 that one specimen for each period was removed from the water after twenty-six days. Those blanks represent the specimen removed, and they are tested later on, you notice, in Table D.

MR. FRASER :—Yes. And then Table E; you have apparently no test for one month and three months in colza-oil in water and air, as no results are given.

MR. GADD :—The tests were made, but those are the results. The results were nil; there was no strength.

MR. FRASER :—I see, they failed utterly. I should just like to add my thanks to those of Mr. Alban Scott and Mr. Butler. I think this is by far the best paper that has ever been read at the Institute. It is astounding the amount of information that is given; in fact, its value is one of its faults, really, for this reason, that so much information is given, and so wisely, that I am afraid members will be acting upon it without asking the question as to how these tests were carried out, and, considering the Concrete Institute publish these, and in a way render them authentic, I think the author might give us some hint as to the actual testing of these cubes. He is a chemist, and we do not doubt for a moment his ability to carry out chemical tests, but I think, as to the actual crushing tests and tensile

tests it should be stated on what instrument these tests were done, and probably by whom.

MR. W. G. PERKINS, District Surveyor for Holborn (Member of Council):—I should just like to say a word. I will not be long. I think Mr. Gadd's paper is most opportune, because at the present time there are in the market a number of patent preparations or compositions which we are told to add to our cement to make it waterproof. Now, I believe some of those patent things are fatty acids; at all events, I was told so in the case I had recently where I took legal proceedings against a builder for mixing a certain powder with his cement and using it for a damp-proof course. I served the builder with a notice, and he would not comply with it. The result was I took him to the police-court. During the course of the case they called an agent for the proprietors of this material, who went into the witness-box and said it was a fatty acid, the composition of which was a trade secret. That did not seem to satisfy the magistrate, and as a result the builder was fined £5. I have since had that damp-course taken out. I do not know whether I was right or wrong in my action. If I always took up that attitude, I might be stopping the use of a valuable article. I should like to know from Mr. Gadd whether he thinks the addition of these materials—I need not mention them by name; you can see them advertised in the pages of all the professional journals—is detrimental to cement and concrete.

MR. FREDERIC W. HINGSTON, M. Quantity Surveyors' Association, M.C.I.:—I should like to say I have recently had experience in taking out the quantities for a reinforced concrete bath which has been made watertight by being rendered on the inside with one of these patent materials with no other waterproofing material at all. I would be very much obliged if Mr. Gadd would tell us, if he can, whether that material has any effect on the concrete either one way or the other. It would be most interesting to me, and I am sure to other members of the Institute.

MR. G. C. WORKMAN, M.S.E. (Member of Council):—While we are on the same subject I would like to ask a question also. I was reading a few

days ago an article—an extract from an American paper—where experiments were given concerning the waterproofing of concrete by the addition of a small quantity of soap. The tests given were very remarkable. Mr. Gadd says in his paper that all the tests that he has made here bring out the destructive action of saponifiable vegetable oil. I want to ask if this means that there is some danger in mixing soap with the concrete, assuming that it has that beneficial effect of making it watertight?

Referring to the whole trend of this paper, I am very pleased to see that it absolutely confirms what I have always held to be a rule for concrete engineers to work upon when dealing with any of these oils or acids, namely, that it seems, by various tests which have been made, that mineral oils do not appear to affect the concrete, whereas animal and vegetable oils seem to affect it—that is, if the concrete is to resist the effects of cold mineral oils. From all the information I have been able to gather from tests and reports from various sources on the subject, all I have read seems to be borne out by Mr. Gadd's experiments, which are certainly of great value, and which I have no doubt will be very useful to reinforced concrete engineers in particular, seeing that they often have to deal with the question of reservoirs and pipes which have to contain fats and acids.

With regard to naphtha and various other mineral oils, I am inclined to think there is no danger in making reinforced concrete reservoirs and pipes to contain this mineral if cold. I have seen small reservoirs filled with *crude mineral oil*, and I have been told that the oil had been standing there for three months without any detrimental effect to the reservoirs. I have been told that at Baku and various other places large reservoirs are used for the storage of naphtha, and, as far as I can find out, they seem all right, but still, there seems to be a certain amount of doubt on the subject, and those who know something about these things keep them secret. I should like Mr. Gadd's opinion as to those very important questions.

MR. VAWDREY :—Just one question, and that is, At what age is concrete sufficiently indurated to resist

the action of mineral oil? It appears it does so after a certain age; at what age does Mr. Gadd consider the dangerous period is past?

THE PRESIDENT :—With reference to the question of waterproofing compounds, I have found in all cases after three months the crushing strength is gradually reduced. I am making some further experiments with waterproofing compounds guaranteed to increase the strength. After about a couple of years I shall be able to give some information on the subject.

I will now ask Mr. Gadd if he will reply briefly to the remarks made by the various speakers. If he wishes to elaborate later on by letter, we will be very pleased to have his communication.

MR. GADD :—Mr. President, I hope I shall be able to answer all the points raised by various speakers, but I am afraid, not being a shorthand writer, that the notes I have are rather scrappy, and I am not sure that I shall be able to make them all out.

To commence with Mr. Butler, if I may. He asked what effect the immersion of cement in beer had upon the setting-time. I am sorry I cannot give that at the moment. I believe I made a note of it, but it is not now within my memory. Then Mr. Butler raised a point which is quite justifiable, and which, I admit, detracts something from the value of the results, although not very much. He drew attention to the facts that the results of crushing and tensile tests are the average of only two or three duplicate tests. I can only say that I should have preferred to make a larger number of tests, but the number is already fairly large, and there is a limit to one's available time and storage-room. As I remarked in introducing the paper, I do not profess it to be an exhaustive treatment of the subject, but, at the same time, I think you may accept the results from even two or three tests as an indication of the truth. My object in bringing this before the Institute was rather to commence a line of investigation, which, I hope, will be followed up not only by myself but by other members.

Mr. Butler suggested that it would have been better to immerse water-gauged briquettes in tannic acid rather than gauge with the acid solution itself. I am

prepared to admit that in one sense this would be true, as it would approximate more nearly to actual conditions in practice, but in another sense this objection does not apply. The object was to ascertain the action of tannic acid on concrete, and gauging the cement with the solution brings the acid into more intimate contact with every portion of the mortar.

Mr. Butler's point about greasing moulds is an excellent one. It did not occur to me to make it in the course of the paper, but you certainly do not grease a mould with the object of causing a briquette to stick to it.

In answer to further questions, the oil or grease was mixed with the dry cement by rubbing in a mortar, the harder fats, like lard, being slightly warmed to enable this to be done. Afterwards the sand was added and the whole well mixed, and finally the mass was gauged with water.

The form of percolator used is rather difficult to describe verbally, but it consists essentially of two cast-iron cups of square form, between which the concrete slab is squeezed by means of large screwed rods and nuts, indiarubber washers 1 in. thick forming watertight joints and cushions. The upper cup is provided with an inlet for water, and the lower cup has an exit, too, for the water, which is forced through the slab. Pressure is obtained by means of a pump, and an accumulator retains the pressure constant, indicated by a pressure-gauge. I shall be glad to give Mr. Butler a sketch afterwards.

Mr. Butler :—Thank you.

Mr. Gadd :—I do not know whether I have answered all Mr. Butler's questions before I leave him. With regard to Table H, he remarked that it was rather curious that test-pieces immersed in cotton-seed oil showed a certain strength at one period and nothing at another. Well, I am afraid I cannot explain that except in one of two ways : either that some of the briquettes, although they were all made by the same gauger, were perhaps a little denser than others ; or, as there are only two briquettes tested, the average is not good enough—there were not sufficient of them to get a fair result.

MR. BUTLER :—Table G especially.

MR. GADD :—What about that? I see what you mean : that it dropped at six months.

MR. BUTLER :—No ; Table G—" Tensile strength nothing."

MR. GADD :—Well, absolutely nothing ; that is quite so. You see, there were only two briquettes tested at each period, but in neither case would they stand the weight of the clips—they had no resistance at all.

MR. BUTLER :—You had a crushing strength over 1,000.

MR. GADD :—Yes ; it is very curious. I do not propose to-night to try to explain it. These are the results I got, and that is all I can say about them.

Now I may leave Mr. Butler, and I hope if I have left anything unanswered he will let me know afterwards. Mr. Alban Scott made some remark about percolation through concrete, and he said he found in his experience that after a time even concrete which was porous closed up. Well, of course, that is the experience of everybody ; it does close up. As the concrete goes on hydrating, setting, and indurating the pores gradually close up, and, personally, I know no better way of making concrete waterproof than to force water through it for an hour or two under very high pressure. If you do that, and then let it dry, it is then almost absolutely waterproof—that is, assuming it is concrete and not a sponge.

Mr. Alban Scott also raised the question as to why two cubes only were tested. I have answered that ; I am sorry there were not more.

Mr. Vawdrey asked me to what extent do I attribute a diminution in the size of the block. I am afraid I did not quite follow him there. I did not measure the blocks, but I did not observe that there was any diminution whatever.

MR. VAWDREY :—In one case the block was actually reduced to mud. I wondered, in the other case, whether that action had been going on from the outside.

Mr. GADD :—Oh, yes ; that is quite right. The edges were worn ; there were no sharp edges. Even in those briquettes which stood a certain amount of strain the outside was rather indeterminate in shape.

Mr. VAWDREY :—Then, to a certain extent, the sectional area had been reduced, I take it?

Mr. GADD :—Undoubtedly. You also asked me to explain the term "saponification." Well, if you attempt to do so simply, it means the decomposition of a neutral oil. When I speak of a neutral oil I want it to be quite understood that the ordinary oils, as we know them, are not fatty acids ; they are compounds of the fatty acids, just in the same way as salt is a compound of hydrochloric acid. But the neutral oils are decomposed by calcium hydrate—we will say split up—and in that process form a soap. As I have explained in the paper, tallow largely consists of tristearin ; it is a compound in which a portion of the hydrogen of the fatty acid is replaced by the glycerin radical C_3H_5, and the process of saponification is merely to dissociate the glycerin radical from the fatty acid. The glycerin is set free, or, rather, the glycerin radical combines with the elements of water, to form glycerin, as we know it ; the fatty acid which was formerly in combination with the glycerin radical goes into combination with the lime. The reason it is called saponification is because the metallic salts which are formed from these fatty acids are all soaps ; hence the term "saponification," or the production of a soap. That is not very clear, perhaps, to you?

Mr. VAWDREY :—Yes, I follow it.

Mr. GADD :—Well, it is not a subject which can be explained in two or three words. You also asked me, Mr. Vawdrey, in effect to reassure you as to my qualifications for carrying out the physical tests which I have given in the paper.

Mr. VAWDREY :—Not I.

Mr. GADD :—Well, somebody did it, I do not know who it was. One speaker was good enough to say no doubt I was capable of making chemical analyses, but he would like to know what my qualifications were for making physical tests. If it is any

assurance to him I may say that I am making these physical tests every day of my life, that I am responsible for all the physical tests made at the Central Laboratory of the Associated Portland Cement Manufacturers, and that these briquettes and cubes were gauged under my supervision by my regular staff, who are expert gaugers.

Mr. FRASER :—I would like to apologize if——

Mr. GADD :—Not at all ; you were perfectly right to ask.

Mr. FRASER :—I thought that would be right to the general public who do not know your name as well as I do.

Mr. GADD :—Do not apologize, you were quite right to ask.

Another speaker, whose name unfortunately I have not got, had something to say about the various waterproofing compounds which are being pushed pretty well on the market just now. Well, I am not interested in waterproof compounds either one way or the other. I have no interest in praising them, I have no interest whatever in damning them, but I have, as a matter of fact, for my own information and the information of my directors, examined, analysed, and tested in relation to their effect upon tensile and crushing strength, and on waterproofing in particular, practically all the water-proofing compounds there are on the market. I may go so far as to say that generally speaking they are all the same ; I cannot at the moment call to mind one which differs from all the rest.

Mr. PERKINS :—May I interrupt, sir? One of them, for instance, is in the form of a paste, another is in the form of a powder.

Mr. GADD :—Yes, but they all agree in principle ; they are all the same.

Mr. PERKINS :—The same in chemical composition?

Mr. GADD :—They are the same material ; one is mixed with water and the other is not, that is all.

MR. PERKINS :—The proprietor of one assures me it will not mix with water.

MR. GADD :—Quite so, neither will it in a way. It is a paste of a sort ; it is an emulsion really. But I may tell you the basis of practically all of them is the same. It is supposed to be this very lime soap or calcium stearate which I mention on page 508 of the paper. There are one or two exceptions, but as a matter of fact the bulk of them (I hope I am not giving away anybody who is present)—the bulk of these compounds consists of hydrate of lime with about 10 per cent. of lime soap. The reason of this is that although supposed to be calcium stearate, owing to the crude way in which the fat is saponified, they only get about 10 per cent. of calcium stearate, and the rest is simply lime and free fat, whether it is mixed with water, as our friend says, or whether it is dry. I quite agree that they may have some action in stopping up pores, so far as the free lime is concerned, that is to say, the lime hydrate, but I find myself that the calcium stearate part of it is a detriment rather than an assistance. I have not found a single one of these lime soap compounds which renders concrete more waterproof than plain concrete, but rather the reverse. In my own tests the lime stearate, which is an insoluble and sticky sort of a material, has been absolutely detrimental so far as making concrete waterproof is concerned.

MR. HINGSTON :—May I ask you a question, sir, upon that?

MR. GADD :—Yes.

MR. HINGSTON :—I ask you because, as I have said before, we have just done a reinforced concrete swimming-bath with this material, and I should like to know whether it has a detrimental effect upon the bath, and whether that effect is likely to be continuous. In other words, will the bath be a failure in the course of a number of years?

MR. GADD :—I do not think so. So far as my experience goes, I find that if you mix these waterproofing materials with concrete there is a loss of tensile and crushing strength which varies from 15

or 20 up to as much as 40 per cent. loss of strength, but the lime soap, which is the chemical basis of these things, is not a fatty acid ; it is a salt of a fatty acid and it has no effect itself upon the concrete.

MR. HINGSTON :—Thank you.

MR. GADD :—My objection to these waterproofing compounds is that they do not make concrete waterproof. I do not say that they damage the concrete.

MR. HINGSTON :—Well, in this particular case it is a swimming-bath, not a particularly large one, and the people guaranteed it to be waterproof.

MR. GADD :—Well, it may be, and I have seen such tanks and baths which are quite waterproof, but my contention is, if you had made the concrete properly without it it would be equally waterproof ; at any rate, that is what my own experiments lead me to.

I think somebody else mentioned about waterproofing with soap. Well, in that case you have absolutely the same thing. If you gauge cement you liberate calcium hydrate ; in contact with soap there is an interchange of lime for soda ; the soda soap is decomposed and this very calcium stearate or lime soap is formed.

MR. WORKMAN :—Does it weaken the concrete?

MR. GADD :—Well, it does, but I do not say seriously. In some of my experiments where 3, 4, or 5 per cent. of the material has been put in, it has weakened the concrete as much as 40 per cent., but that is the limit I have found. It certainly does not help the concrete.

Mr. Workman also said he found that mineral oils do not affect concrete. I am quite with him there. I think it is perfectly safe to store mineral oil in a concrete tank, if it is entirely mineral oil. It certainly is not safe to store vegetable or animal oil in concrete tanks, but mineral oil, which is not saponifiable, I think it is perfectly justifiable to store in a well-made concrete tank.

MR. WORKMAN :—It will not affect them?

MR. GADD :—It will not affect the concrete chemically, although my experiments indicate some

loss of strength for physical reasons. The difficulty is that in most cases you cannot make the concrete sufficiently tight; light oils percolate through.

Mr. WORKMAN :—That is the point.

Mr. GADD :—They are not doing the concrete any harm chemically.

Mr. WORKMAN :—I have been told this, that if these heavy oils are very much refined they become so light that they simply go through the concrete.

Mr. GADD :—That is quite right.

Mr. WORKMAN :—I have no evidence to show whether that is so or not. I am concerned with the storage of benzoline; as a matter of fact, it is a very volatile oil.

Mr. GADD :—Personally, I have not been able to make any concrete dense enough to prevent benzoline going through it.

Mr. WORKMAN :—That is what I fear, too.

Mr. GADD :—I think you will find the greatest difficulty to keep it in, but so far as acting on the concrete is concerned there is no danger whatever.

The Meeting then terminated.

THIRTIETH ORDINARY GENERAL MEETING

Thursday, January 9, 1913

THE THIRTIETH ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held in the Lecture Hall at Denison House, 296, Vauxhall Bridge Road, London, S.W., on Thursday, January 9, 1913, at 7.30 p.m.,

Mr. E. P. WELLS, J. P. (the President), presiding.

THE PRESIDENT :—The first business, gentlemen, for us this evening is to elect eleven members and two students, whose names I will put before you, and unless I hear to the contrary I will assume that they are elected.

1. Mr. Percival M. Cooper, Chief Engineering Assistant with Messrs. Mais and Sant, A.M.M.I.C.E., Kingston, Jamaica.

2. Mr. William Walker Dearle, M. Quan. Surv. Assoc., 13, John Street, Adelphi.

3. Mr. J. V. Haskell, Assistant Engineer in Railway Construction, P.W.D., Wellington, New Zealand.

4. Mr. Frank Hill, Engineer-in-Chief's Office, General Post Office, 8, King Edward Street, E.C.

5. Mr. Frederic William Hingston, M. Quan. Surv. Assoc., Portland House, Basinghall Street, E.C.

6. Mr. Andrew Little, Engineer with Ocean Iron Works, Manchester.

7. Mr. William Alexander Mackay, Structural Engineer, 94, Larkhall Rise, Clapham.

8. Mr. Charles Newson, M.S.A., 92, Tooley Street, London Bridge, S.E.

9. Mr. P. V. Manickam Naicker, B.E., Executive Engineer, P.W.D., Madras.

10. Mr. R. Vittal Rau, Supervisor, c/o the Special Engineer, Hyderabad, Deccan, India.

11. Captain Arthur Johnson Savage, R.E., First Assistant Superintendent, Building Works Department, No. 4, Staff Quarters, Royal Arsenal, Woolwich.

1. Mr. Archibald John Buchanan Atkinson, Stud. Inst. C.E., Assistant Civil Engineeer, North Staffordshire Railway Company, Engineer's Office, Stoke-on-Trent.

2. Mr. John P. Harvey, Draughtsman with Mr. Alexander Drew, M.I.Mech.E., 64, Victoria Street, S.W.

This brings the total number of members up to date to 955.

I will now call upon Mr. Valentine Ball to read his paper on "Concrete in its Legal Aspect."

Mr. W. VALENTINE BALL, Barrister-at-Law, then read his paper.

CONCRETE IN ITS LEGAL ASPECT

Preliminary.

In presenting this paper one is beset with certain difficulties. There is no statute law which is specially applicable to the subject in hand, and of reported cases relating specially to concrete there are none. Nevertheless, it has occurred to me that there are certain aspects of the law relating to building and engineering contracts which may be of interest to members of this Institute, and I am indebted to your Council for giving me this opportunity of setting them before you. I hope to draw attention to a few considerations which may properly be kept in view by the parties to a contract which involves the use of concrete or reinforced concrete.

I was prompted to prepare this paper by the fact that I recently came across a contract for the erection of large works which involved the use of 30,000 tons of cement! It therefore occurred to me that the clauses as to concrete and reinforced concrete which

appear in engineering and building contracts are by no means a negligible part of these documents.

In the course of the paper I propose to use the term "employer" to mean the local authority, company, or person who requires the work to be carried out. The term "contractor" will signify the firm of contractors or builders employed directly by the employer, while the term "sub-contractor" will include any firm or company which is employed to carry out some portion of the work under a sub-contract.

General Observations on the Employment of a Sub-contractor.

Your Secretary has been good enough to point out to me that the relations between contractor and sub-contractor are likely to be of special interest to members of the Institute.

In carrying out a large contract the employment of sub-contractors or specialists is very common; indeed, the employment of sub-contractors is almost inevitable when the work in hand is of any magnitude. Whether the work of making ordinary concrete is usually entrusted to a sub-contractor I do not know. But I presume that reinforced concrete will frequently be carried out under a sub-contract. The sub-contractor will be chosen by the engineer or architect acting in the interests of the employer.

Generally speaking, where there is no stipulation against sub-contracting a contractor may employ sub-contractors. The rule is, however, subject to the qualification that it does not apply when the employer reasonably and naturally looks for the personal service and attention of the contractor. Thus, if the work in hand were of a highly special character, it would not be competent for the contractor who was skilled in that class of work to hand over its performance to some one else. It is otherwise, however, when the work involves the exercise of no special degree of skill. Cockburn, C. J., in *British Waggon Co.* v. *Lea*, 1880, 5 Q.B.D. 149 (at p. 153), thus stated his views of the law on the subject:—

"Much work is contracted for which it is known

can only be executed by means of sub-contracts; much is contracted for as to which it is indifferent to the party for whom it is to be done whether it is done by the immediate party to the contract or by some one on his behalf. In all cases the maxim *Qui facit per alium facit per se* applies." For instance, if I were to employ Messrs. A B to make a reinforced concrete bridge, that firm being particularly skilled in the work, they could not let the work out to Messrs. C D.

Although there does not appear to be any English case on the point, it appears that neither an architect nor an engineer has implied authority to employ sub-contractors to do any part of the contract work, or any work which is extra to that work. The law has been so laid down in Canada (see *Cowan* v. *Goderich Northern Gravel Co.*, 1859, 10 Up. Can. C.P. 87, cited in Hudson's "Building Contracts," vol. i., p. 161). In that case the plaintiff was a sub-contractor employed by head contractors who were constructing a road for the defendants. The defendant's engineer instructed the plaintiffs to do certain work for the price of which the action was brought. It was held that the action did not lie, as the engineer had no authority to give the order in question. The following clause may be inserted if it is desired to ensure that the contractor shall carry out all the work himself:—

> "This contract is and shall be considered as a personal contract by the contractor himself, who shall personally, with the assistance of skilled foremen, agents, mechanics, and workmen, direct and execute the works."

The more approved practice, however, is to leave it to the engineer to say whether and how far sub-contractors may be employed. The following clause, which is to be found in the model conditions approved by the Institute of Electrical Engineers, may safely be used:—

> "The contractor shall not, without the consent in writing of the engineer, assign his contract, or any substantial part thereof, nor under-let the

same, or any substantial part thereof, nor make any sub-contract with any person or persons for the execution of any portion of the works, other than for raw materials, for minor details, or for any part of the whole of which the makers are named in the contract."

Another form of clause prevents the contractor from making a sub-contract with any workman or workmen for the execution of any portion of the work, except with the consent of the engineer. It also provides that if the contractor shall sub-let or let at task work any portion of the work he shall in such case forfeit to the employer the sum of £100 as liquidated damages.

WHO IS LIABLE TO PAY THE SUB-CONTRACTOR?

A most important question from the point of view of the sub-contractor is, Who is liable to pay him? He naturally wants to be sure that his labour will not be in vain. Generally speaking, the employer is not liable to a sub-contractor, unless an agreement between them can be proved. Such an agreement will not be implied from the mere acceptance of the sub-contractor's work. Thus, if A were to ask you to lay the concrete foundations for B's house, and you did the work, the mere fact that B accepted it and thanked you very much, would not make him liable to pay for it. For instance, where an employer contracted with a builder to do certain work on his house, and a tradesman supplied goods to the builder for use on the house, it was held that the employer was not liable for their price (see the case of *Brahmah* v. *Abingdon*, cited in *Paterson* v. *Gandasequi*, 1812, 15 East. 62). The employer does, however, become liable if it can be shown that there is a contract between him and the sub-contractor. For instance, in another case a contractor employed a mason to do certain work as extra to the contract. In an action for work and materials by the mason against the contractor's employer the plaintiff stated that the work in question was extra to the contractor's contract, and that he had agreed with the contractor to do the work. On production of the contractor's contract the jury

found that there was a distinct contract between the mason and the employer for the work sued on, and judgment was entered for the plaintiff (*Eccles* v. *Southern*, 1861, 3 F. and F. 142).

An employer may also become liable to a sub-contractor by going surety for him. In that case, however, there must be something in writing, as a contract of guaranty cannot be sued on unless it is in writing. But there is a difference between a promise to pay the debt of another and a direct promise to be liable oneself in any event. In the latter case a written contract need not be proved. Thus, if the employer promises to pay the sub-contractor out of monies which he has to pay to the head contractor, this would be treated as a direct promise to pay (*Dixon* v. *Hatfield*, 1825, 2 Bing. 439).

There is another way in which the employer may become directly liable to a sub-contractor. It may be proved that the head contractor, in employing the sub-contractor, really acted as the agent for the employer. The *onus* of proving this will be on the sub-contractor (see *Woodward* v. *Buchanan*, 1870, L.R. 5 Q.B. 285).

The question, Who is the sub-contractor to look to for his remuneration? therefore turns upon the conditions of his employment. In the ordinary form of agreement a clause is inserted providing that the contractor will pay to the sub-contractor "the sum of £ when the engineer for the time being of the employer shall have certified in writing that the said work has been completed and finished to his satisfaction." Other terms are sometimes inserted providing for payment by instalments.

The question of liability largely depends upon whether the contractor was constituted the agent of the employer to employ the sub-contractor or to purchase goods from him, and to establish privity of contract between the employer and such sub-contractor. Where the defendant (a building-owner) entered into a contract with a builder by which the latter agreed to build a house for him under the supervision of an architect, the contract provided that the provisional sums for goods to be ordered from special artists or tradesmen should, as the architect should certify, be

payable by the builder or the building-owner. The exact terms of the clause were that :—

> "The provisional sums mentioned in the specification for materials to be supplied or for work to be performed by special artists or tradesmen, or for other works or fittings to the building, shall be paid and expended at such time and in such amounts and to and in favour of such persons as the architect shall direct, and sums so expended shall be payable by the contractor without discount or deduction or by the employer to the said artists or tradesmen."

Special goods according to a particular design were ordered by the builder from the plaintiff, who was a metal-worker, and the architect certified the sums for these goods as due from the defendant to the plaintiff, deducting the amount from the certificate given to the builder. It was held that the plaintiff was entitled to recover this sum direct from the building-owner (*Hobbs* v. *Turner*, 1901, 18 T.L.R. 235, which was followed by Mr. Justice Channell in the recent case of *Cuttall* v. *The London County Council* (1910), 75 J.P. 203). In the absence of such a clause, a specialist or sub-contractor would be compelled to look for his remuneration to the person who directly employed him—namely, the head contractor.

Where the Contractor becomes Insolvent.

Trouble frequently arises in cases where, owing to the insolvency of the builder, the sub-contractor is compelled to look to the building-owner. He often makes such a claim without avail ; but by means of a special clause this difficulty may be obviated. So *In re Wilkinson* ex parte *Fowler* (1905, 2 K.B. 713), a District Council entered into a contract with a contractor for the construction of certain sewerage works. The contract provided that certain machinery for the works was to be supplied to the contractor by certain specified firms, and that "if the engineer shall have reasonable cause to believe that the contractor is unduly delaying proper payment to the firms supplying the

machinery, he shall have power, if he thinks fit, to order direct payment to them." The contractor having become bankrupt, it was held that the engineer had power to direct the payments to be made to the machinery firms direct. Mr. Justice Bigham said: "I think that the clause means that if the persons supplying machinery to the contractor for the purpose of the contract are not promptly and properly paid by him they can apply to the engineer, and then it shall be competent for the engineer to intervene, and by a proper certificate given in that behalf to require the council to pay to the machinery firms the amount of their accounts directly—that is to say, not through the hands of the contractor at all, but the money is to be paid directly by the council to the machinery firms."

How far the Contractor is Liable for the Delay of the Sub-Contractor.

Assuming there is delay in the execution of the work, the question of liability may arise as between the contractor and the sub-contractor. One may blame the other, and the employer may leave them to fight it out between themselves.

If an employer reserves to himself the right of employing specialists to do any portion of the work on a large contract, he does not thereby give any implied undertaking to the head contractor that he will be responsible for any damage caused to the builder by any delay or default on the part of the specialists. In the case of *Mitchell* v. *Guildford Union* (1903, 68 J.P. 54) a builder undertook to do the whole of a certain piece of work for a certain sum, but part of it was to be done by specialists. The builder undertook to finish the work by a certain date unless he was hindered by (*inter alia*) delay on the part of the engineer or specialists. The builder was not to be liable for any defects in work provided by the specialists, unless by the reason of contributory negligence on his part, or his having paid any final balance to the specialists without first having the architects' written authority to do so. In the course of the work there was delay on the part of the specialists,

whereby the builder suffered damage. The builder brought an action for breach of contract against the building-owners, alleging that under the contract and specification there was an implied promise on the part of the building-owners that the delivering and pricing should be done at such reasonable times as to enable the builder to complete his work within a reasonable time thereafter, and that the building-owners had broken one or both of these implied promises. It was held that on the proper construction of the contract and specification there was no such implied promise, and that there was no breach of contract on the part of the building-owners affording the builder a right to damages. (See also *Leslie* v. *Metropolitan Asylums District*, 1901, 68 J.P. 86.) As a general rule, however, the sub-contract contains a clause to the effect that "the sub-contractor shall pay to the contractor the sum of £ as liquidated damages, and not by way of penalty per day for each day after the day of that the work shall not be finished or complete, and it shall be lawful for the said contractor to retain the said sums out of any money payable to the sub-contractor."

Liability of the Sub-Contractor for Delay.

The liability of a sub-contractor for delay in completing the work he has undertaken to carry out depends on the terms of his contract with the head contractor. If he does not know that the head contractor has undertaken to do the work within a specified time, he will not be liable for the damages claimed and recovered by the employer for delay; but it is otherwise if it is shown that he knew what would be the consequences of delay. These principles may be illustrated by two cases. In the first of these (*Portman* v. *Middleton*, 1858, 27 L.J.C.P. 231) the plaintiff contracted with a person who may be termed the employer to repair a machine. Part of the machine consisted of a firebox which the defendant was employed to make within a certain time. Owing to the firebox not being supplied within the proper time, the plaintiff was unable to complete his contract with the employer, who sued for and recovered damages.

It was shown, however, that the plaintiff would have had time to get another firebox elsewhere. The present action was brought to recover from the sub-contractor the damages paid to the employer. It was held that the damages paid could not be recovered, inasmuch as the terms of the contract with the employer were unknown to the sub-contractor, but that the plaintiff could recover from the defendant the sum of £82 which he had originally paid to the manufacturers and the extra cost required in getting another firebox elsewhere. In the other case (*Hydraulic Engineering Co.* v. *McHaffie*, 1878, 4 Q.B.D. 670) the plaintiff company contracted with an employer to make a pile-driving machine. The defendant was employed to make a part of the machine and to deliver the same by the end of August, when, as he knew, the plaintiff company had to make delivery to the employer. The defendant was a month late in making delivery of his part, with the result that the employer refused to accept the whole machine. As it was of peculiar construction, no market could be found for it, and it was therefore sold as old iron. It was held that the plaintiffs were entitled to recover the profits which they would have made on the sale to the employer and the expenditure thrown away on the other parts of the machine. From this it may be inferred that any sub-contractor for the execution of a portion of a contract for large works may find himself cast in very considerable damages if he is guilty of delay.

Use of Material on the Site.

It may well be that in some cases the builder or other person who has to provide concrete will find a large bed of gravel or other useful material on the site. How far can he use it in the fulfilment of his contract?

An obligation upon a contractor to clear away old materials does not necessarily vest those materials in him. Again, where a contractor is bound by his contract to excavate, the materials excavated do not necessarily vest in him. On the contrary, if a contractor make use of materials supplied to him, the

employer may set off their price against the amount due under the contract. For instance, in one case the plaintiff contracted to do certain work for the defendant and to find the materials. The defendant supplied part of the materials which the plaintiff made use of in the work. It was held that the defendant was entitled to deduct the value of the materials supplied by him from the contract price (*Newton* v. *Forster*, 1844, 12 M. and W. 772).

The importance to the employer of some clause dealing with old materials lies in the fact that if nothing is said about them the contractor may remove them. Having removed them, he may sell them. In that case, if he were to become bankrupt, the employer could not get the goods back, but would be relegated to his right of proving for their value in the contractor's bankruptcy.

Where the contract for erecting a building or executing other works makes no reference to old materials, it seems that the contractor will be under an implied obligation to clear them away. There is no English case directly in point, but the principle has been laid down in several American cases. In one of these (*Shipman* v. *District of Columbia*, 1886, 119 N.S. 12 (Davis, 148)) a contract provided for the construction of a wall at so much per cubic yard. Nothing was said about the excavations for the wall. It was held that no extra pay could be recovered for making them.

Importance of Providing for the Removal of Old Materials.

It is well for every contractor who has undertaken works which involve the clearance of a site to take care that he is adequately protected. The removal of a large mass of concrete would be a long and costly operation, while to remove reinforced concrete, knit together with ribs of steel, is the labour of Titans. When the time arrives for the removal of modern buildings, it is clear that the contractor must needs regard clearances as a very important item when considering the amount of his tender.

Express Provision for Materials on Site.

In drawing his specification, the architect often inserts a clause to the following effect :—

> "Materials on the site to be used as far as possible."

If a tender is made by a contractor on the basis of such a specification, the architect should take care to ascertain whether the contractor has made any deduction in respect of old materials. If the contractor, having made no deduction, uses any of the materials, the architect may set their value off against the contract price ; and even if the contractor has made a deduction, but has not informed the architect of the fact, there may still be a set-off. For instance, in *Harvey* v. *Lawrence*, 1867, 15 L.T.N.S. 571, the plaintiff, a builder, sued for the sum of £800, the contract price payable on completion of the works. The architect had certified that the work was completed. The contract contained the following clause :—

> "All old lead to be displaced by new is to become the property of the contractor, who will make a due allowance for the same."

The defendant employer pleaded a set-off of £38, the value of old lead. It was held that as the contractor could not prove that he informed the employer or the architect that in making his estimate he had allowed for the value of the old lead, the set-off was good.

Clause to Provide for the Use of Old Materials.

The following is a convenient form of clause :—

> "All materials upon the site or upon the space to be covered by the buildings [or contract works] at the date of the contract, and all materials and things excavated by the contractor from the works, shall remain the property of the employer until paid for by the contractor. Such of them as

shall be approved by the architect for the purpose of the works shall be paid for by the contractor at a price to be named in his tender or, if not named, to be ascertained by the architect, and all other materials shall be removed by the contractor from or deposited, stacked, or spread on the site as where and when directed by the architect."

This clause may properly be inserted in a contract which involves the making of concrete, because it is necessary that gravel, etc., to be used should be approved by the architect.

Provision for Water.

Another question of importance is the provision of an adequate supply of water. Where there is a good supply at hand in the mains no difficulty need arise. The question will simply be, Is the employer or the contractor to pay the water rate during the work of construction? But if there is no municipal or other supply the difficulty may have to be met by sinking a well or pumping from a lake or river. Suitable clauses must be inserted in the contract to place the burden of pumping or well-sinking on the right shoulders.

Right to Reject Materials.

It is important to consider the question whether the architect has the right to reject improper materials when brought on to the works. In this regard the provisions of the R.I.B.A. form appear to be fairly satisfactory.

Phillimore, J., made the following observations upon Clauses 16 and 17 of that form: "Happily in this case I think I have not to definitely construe Clause 16, but it occurs to me that the real businesslike way to construe it is to apply it to emergencies, to things that arise in the immediate course of building which require rather executive than judicial action followed immediately by the judge carrying out his judgment. If a stack of bricks are bad bricks in the sight of

the architect for the class of work which is going to be done, and he rejects it, if there is a piece of 'green' work built, the architect or clerk of the works may say, 'That is badly done and must be pulled down and rebuilt.' But when the architect has looked at the work on one of these visits, and has not condemned it, and the contractor has obviously treated it as finished and taken his men off from it, and proceeded to another piece of the work, it occurs to me that Clause 16 ought not to apply. If, in fact, the work is badly done, and mischief follows in consequence, the architect is not without his power, and the employer is not without his protection. The architect then uses Clause 17, and applies the retention money, and in that case he is no longer acting on an emergency. He is acting judicially, and only judicially, and there is the appeal from him to the arbitrator. That seems to me, if and so far as I have to decide it in this case, to be the way of reconciling Clauses 16 and 17" (*Adcocks Trustee* v. *Bridge R.D.C.*, 1911, 75 J.P. 264). The clause in question is that in which power is given to the architect to order the removal of improper work and to provide for defects after completion.

Supervision when Concrete being Laid.

Concrete is a matter which may require some supervision on the part of the architect. To cover up wet concrete may involve serious disaster, and it seems that, in the conduct of ordinary building operations, it is the duty of the architect to attend to this matter; although in some respects he is an arbitrator, he is also a servant to the building-owner or employer.

If it is true that dry-rot is a defect which will occur in any house, however it may be constructed, it is clear that liability to put it right cannot be fixed upon any one, unless it is specially provided for in the contract. But in the few cases which have been before the courts it has been assumed or proved that dry-rot is a defect which may be caused or brought into existence by bad design—chiefly in matters relating to ventilation—or by bad supervision in the construction of works.

It is proposed to consider some of the cases bearing on the subject. Thus, the fact that an architect may be held liable for negligence for passing bad work is illustrated by a case where the plaintiff employed a builder to build a house for him in accordance with certain plans. The builder was to be paid on the certificates of the defendant, who was the plaintiff's architect. The defendant certified, and the plaintiff accordingly paid the builder. This action was brought by the plaintiff, who alleged that in consequence of the defendant's negligence in superintendence the house was not built in accordance with the contract. The jury found a verdict for the plaintiff.

The fact that an architect may be held liable for dry-rot has been clearly established in a Scotch case which is noted in *Emden's Building Contracts*, 4th ed., p. 78. There a builder was employed to build a house to the specification of the defendant, an architect. No clerk of the works was employed. Many months after the completion of the work the whole ground floor became infected with dry-rot. The building-owner made a claim upon the builder, who denied all liability. He then brought an action against the architect, claiming damages for negligence. The Court of Session in Edinburgh held that the architect was liable.

In the course of the judgment in that case it was stated that : "To some extent an architect is an artist —that is, as regards the design and plan. But for the rest his work is just ordinary tradesman's work—drawing specifications and supervising the work. He is not supposed to do all the supervision personally. His substitute can do much of it as well as he can himself ; but if he undertakes to do it he is bound either to do it himself or to have it done by some person whom he employs in whom he has confidence. I think the meaning of the contract is that he shall see that the work is done well before he certifies it.

"There may, of course, be many things which the architect cannot be expected to observe whilst they are being done—minute matters that nothing but daily or even hourly watching could keep a check upon. . . . But he, or some one representing him, should undoubtedly see to the principal parts of the work

before they are hid from view, and if need be, I think he should require a contractor to give notice before an operation is to be done which will prevent his so inspecting an important part of the work as to be able to give his certificate upon knowledge, and not on assumption, as to how work hidden from view has been done."

A very similar decision was arrived at in the King's Bench Division in relation to the building of an asylum for the Leicester Board of Guardians.

So much for the liability of the architect. In a case where there is no architect employed the problem assumes a somewhat simpler aspect. The builder then acts as skilled adviser, as designer, and as superintendent of the building.

Defects after Completion.

I have not sufficient technical knowledge to know whether concrete or reinforced concrete is liable through the mere lapse of time to deteriorate. I remember having heard that "Roman cement," which was used in the building of portions of the Eternal City, was sometimes more durable than the stones which it was used to bind together! In anticipation, however, of the fact that some member of the Institute will enlighten me, I propose to say a few words as to defects after completion.

Take, for instance, the case of a concrete archway. Suppose that it develops a crack within six months of the date of completion, and the contract is silent on the question of liability—what is the legal position? The mere fact that the employer has accepted the bridge and paid for it would not amount to a waiver of his right to damages if the bridge failed through some fault for which the contractor was responsible.

For instance, in one case the plaintiff, a shipowner. bought copper sheathing of the defendant, a copper-manufacturer, and the copper was put on the ship, which sailed; but the copper, instead of lasting four or five years, as usual, corroded in four or five months and became unfit. It was held that the plaintiff could recover damages, notwithstanding the acceptance (*Jones* v. *Bright*, 1829, 5 Bing. 533).

Further, payment of, or judgment for, the contract price is no bar to claim by the employer for defective work, nor for damages arising out of the breach (*Davis* v. *Hedges*, 1871, L.R. 6 Q.B. 687).

Advantage of having a Time Limit to Liability for Defects.

From the point of view of the contractor who has to put in concrete, it is best to put a definite period to his liability by an express clause in the contract, because where work is agreed to be done to the approval of the employer or his architect, the expres-tion of that approval will prevent any recovery by him for *patent* defects subsequently discovered. So where one Thompson, a builder, contracted to do certain work for Lord Bateman to the satisfaction of Lord Bateman and his architect, the contract provided that if the use of improper materials, or any non-performance of the contract, appeared within twelve months after completion, Lord Bateman should be entitled to bring an action against the builder, any certificate of the architect notwithstanding. The works were completed, the architect granted his certificate, and Lord Bateman implicitly expressed his satisfaction and paid. More than twelve months afterwards it appeared that bad materials and workmanship had been employed, yet it was held that Lord Bateman had no claim against the builder (*Lord Bateman* v. *Thompson*, 1875, 2 H.B.C. 23).

Where the contract is silent in the matter, the measure of damages for incomplete or defective performance is what it would cost to rectify the defects or omissions at the date when they might have been discovered, or when the particular part of the work was completed.

Apart from the terms of the contract, it is manifest that the contractor could not by any possibility be held responsible for defects arising in the course of time from wear and tear. But if there is a structural defect which ought to have been detected and put right when the works were in hand, it is conceived that the contractor remains liable for that.

Unforeseen Difficulties in Carrying Out the Work.

There is one matter to which the contractor who has made himself responsible for the laying of a large bed of concrete must pay particular attention. The employer will endeavour to put upon the contractor the entire responsibility for the site—the nature of the strata to be met with when making excavations and their capacity to support the intended structure; and he will also seek to put upon the contractor the responsibility of estimating how much material will be necessary to complete the work.

It is a well-established principle of law that in the performance of an ordinary building agreement or other contract for works, the risk of possibility of performance is on the contractor. In *Thorn* v. *Mayor of London*, 1876, L.R. 1 A.C. 120, it was held that the contractor who erected the old Blackfriars Bridge was responsible for the fact that the foundations for the caissons were exceedingly difficult to obtain. Lord Chelmsford pointed out that the contractor, in the exercise of common prudence, should have made investigations for himself. The Corporation, in fact, were held excused by the fact that they disclaimed responsibility for the accuracy of the plans.

The principle of *Thorn* v. *Mayor of London* was long applied to excuse employers in cases of a similar kind; but a more recent case has shown that the disclaiming clause will not necessarily relieve the employer. If he puts forward plans, etc., as showing the nature and extent of the work, he may be held liable if those plans were false to his knowledge or were put forward recklessly without proper inquiry as to whether they were true or false.

In *Pearson* v. *Dublin Corporation*, 1907, A.C. 357, the plaintiffs had undertaken to carry out certain harbour works on the strength of certain plans and drawings of which, however, the Corporation did not guarantee the accuracy. Indeed, they expressly disclaimed liability. The plans were inaccurate. The contractor completed the works at a greatly enhanced cost, and sued the Corporation for damages for fraud. The House of Lords held that there was evidence

adduced at the trial from which a jury might possibly infer that the representations were dishonestly made, or made with a reckless indifference whether they were true or false by the servants of the Corporation. The case was ultimately sent back to a jury for decision.

Let me refer you to the exact terms of the clause which was discussed in Pearson's case, for the reason that you may one day have to consider it yourselves :—

> "The contractor is to satisfy himself as to the dimensions, levels, character, and nature of all existing works, buildings, roads, lands, waterways, sewers, pipes, the nature of the strata through which the excavations are to be made, and all other things so far as they may have any connection with the works in the contract, and is to obtain all his own information on all matters which can in any way influence his tender. He is also to check the estimate of quantities, and satisfy himself as to its accuracy and sufficiency, and the contractor is at liberty to alter or add to the same, if he considers necessary, before sending in his bill of quantities. Any alteration, however, made to the specification or to the schedule of prices will vitiate the tender. No charges for extra work or otherwise will be allowed in consequence of any incorrect information or inaccuracies which may appear on the drawings, specifications, or estimate of quantities. No allowances will be made on account of excavating in rock or other difficult ground, or of unforeseen difficulties of any kind."

Clauses Dealing with Cement.

Certain points occur to me as requiring attention in contracts relating to the supply of cement. Thus, provision must be made for testing by a person responsible to the employer, and for suitable accommodation in a dry place. In the case of a very large contract it may be necessary to erect a special building for the storage of cement until it is required for use. In that case it will be necessary to specify who is to erect the building.

Conclusion.

I have now endeavoured to put before you a few of the questions which are of interest both to the lawyer and the contractor. In the discussion which I hope may follow you may perhaps be able to suggest some other problems of practical interest, with which I can deal in reply.

DISCUSSION.

THE PRESIDENT :—Gentlemen, I have a letter from Mr. Percy Waldram, who is unable to attend this evening, which I will read out to you :—

> "Mr. Ball's interesting and valuable paper would appear to have omitted one point, which might possibly be of the greatest possible importance—viz.,
>
> "Who is responsible in the event of failures due to over-daring design?
>
> "In many cases where reinforced concrete is used the engineer or architect is not in a position to check the calculations. He employs a specialist firm to design and calculate the work, receives from them a price, and instructs the general contractor to give them the order. The latter merely carries out that instruction. In due course the specialist firm send on to the work, not their own workmen but the workmen of a second sub-contractor employed by them. In the case of a public contract which came before my notice not long ago the Local Government Board Inspector asked who would be responsible for the accuracy of the calculations. The prospective contractor was in this case a licensee of the specialists' system. He promptly disclaimed responsibility for calculations which he had never seen, and could not follow if he had. The local engineer said the same, whilst the specialists replied that they were employed to design only, and that if they designed in accordance with ordinary practice their responsibility was at an end; they were not parties to the contract, and had no more responsibility than the local engineer.

" Probably all three were perfectly correct, but the members of the local Council were not impressed.

" It is not always easy to get proper calculations. Sometimes when drawings are submitted to me to check the design and calculations I know from a glance at the name on the prints that it will be easier and quicker in the long run to start a complete series of fresh calculations. A case recently occurred of a slab roof to a vault partly under a roadway where the shear due to the possibility of a traction-engine wheel had been entirely overlooked. This might have happened five minutes or five years after the centering was struck.

" Probably the responsibility might have been fixed upon some one on the ground of culpable negligence. But upon whom? The specialist firm might plead that in the case of intricate calculations their duty had been fairly met by employing responsible draughtsmen ; in the same way that a quantity surveyor pleaded successfully that no professional man could go through all the calculations, and that he had employed well-paid, well-trained, and reputable assistants.

" Still more difficult would be the case where a failure occurred with regard to some of the matters upon which we are still somewhat hazy. Even the R.I.B.A. Reports and the proposed L.C.C. Regulations are almost entirely silent with regard to double reinforced beams.

" Possibly Mr. Ball could suggest some form of undertaking which would fix the responsibility for reinforced concrete work upon the shoulders of the specialist firms who design it, and upon their sub-contractors who carry it out, and also tell us whether that undertaking could be a joint and several one, and for how long it would operate in the event of no time limit being stated."

MR. E. FIANDER ETCHELLS, F.Phys.Soc., A.M.I.Mech.E. (Member of Council) :—Mr. President, I would rather speak later on in the evening,

because the author's paper has dealt principally with the contract side of the legal aspect of concrete. There are many members here who have something to say on the contract side; my own remarks will refer to the constructional side of the legal aspect.

MR. A. ALBAN H. SCOTT, M.S.A. (Member of Council):—Mr. President, I am sure the Institute as an institute and each individual member will be most thankful for Mr. Valentine Ball's paper this evening. It is so unlike the usual legal papers: it is put in a form so that the ordinary layman can understand it, and it follows out the intelligible form which the author of the paper adopted in Emden's "Building Contracts," which is one of the clearest books on building contracts.

The gentleman who wrote the letter which you have just read raises, I think, some of the most important points that can be raised with regard to reinforced concrete work. As I have stated before, the usual custom in building contracts has been, and is being, entirely departed from in reinforced concrete work. It is unfortunate, but the fact remains. I had jotted down here five different methods in which "specialists" may come in. I think it is a little different from that quoted in the letter.

First (*a*) the employer, (*b*) the architect in the usual way who designs his own work, and then (*c*) the contractor, that is the usual method. Secondly, there is (*a*) the employer, (*b*) the architect; then there are the "specialists," who are designers only to the architect. What I mean by that is the architect invites certain "specialists" to prepare plans or details for the reinforced concrete work. All particulars received from him are embodied in the contract with (*c*) the builder. The third is the same as No. 2, but where the "specialist" designs for the contractor; No. 4 is the same as No. 2, but where the "specialist" designs and supplies the steel of some special shape to (*c*) the contractor; and 5 is the same as No. 2, but where the specialist supplies and designs the steel, and takes on the contract for the reinforced concrete work, and then sublets the construction of the centering for the

concrete and other work, but still retains the concrete reinforced with steel.

I think these five among other methods are considerably used to-day, and with the various cases Mr. Valentine Ball has quoted as to sub-contractors it is placing both the architect and eventually the building-owner in a most extraordinary and uncertain position, because each case depends greatly upon the details of each particular contract.

The only thing that I can see that would cover him is the usual clause in the R.I.B.A. form with regard to sub-letting, which is a very short and concise clause. It simply says that the contractor shall not sub-let without the architect's written sanction, and naturally before he gives that written sanction he would clear up some of those points which Mr. Valentine Ball points out ; so he gets a little relief in that way, but the complications, I think, still exist.

The case of *Crittall* v. *The London County Council* raises difficulties to the layman ; assuming the contractor drafts a clause that the employer may pay direct to the sub-contractor, supposing the builder goes bankrupt after he has received all his money, but before he has paid his sub-contractor, does that mean that the employer is liable to the sub-contractor ?

It raises another difficulty, too, because architects get into, no doubt Mr. Valentine Ball would say, a very bad habit of communicating direct with the sub-contractors (but in special things it is a convenient way and saves a lot of time and correspondence with the builder) ; and I have often come across a case where an architect's letter to a sub-contractor might be taken, in a legal sense, without any intention on the part of the architect, as a direct order or as implying that the builder is acting as agent for the employer.

So far as the builder and the sub-contractor are concerned with regard to penalties, the Master Builders' Association have a sub-contractors' form which is based on the R.I.B.A. form, and it there gives in the form of a schedule the whole of the main contract so far as it applies to the sub-contractor, and the sub-contractor has a right to inspect the main contract. I think that gets over lots of difficulties between these two parties.

It is a very good contract, and I think used a good deal.

On page 542 of the paper there is a clause qouted as follows :—

> "All old lead to be displaced by new is to become the property of the contractor, who will make a due allowance for the same."

Without Mr. Valentine Ball's statement I should certainly have interpreted this as meaning that the contractor had already made his allowance in the tender, and it seems surprising that the employer was able to claim £38 as a set-off, after the tender was in, when the clause was, I presume, originally in the specification. Does the author mean that unless the credit is shown by a separate item the allowance can be deducted ?

On the question of dry rot a case arose a little time ago in which dry rot occurred in some wood blocks laid similar to those in this hall. It was after the retention money had been paid. The blocks appeared when laid and for some months to be of proper and good material. It was eventually found that the blocks were made from old ship's timber and the ship had been affected with dry rot. In this case the architect took, to my mind, every reasonable precaution in the inspection of the work and the builder knew perfectly well where the timber came from. Would or would not the builder be responsible for that defective work after the retention money had been paid ? I do not think he put it in with any dishonest intention, because he paid a fair price for it.

On page 546 Mr. Valentine Ball quotes that the architect should require a contractor to give notice before principal parts of the work are hidden from view, as it will enable him to inspect the important part of the work and give a certificate on knowledge and not upon estimation. In reinforced concrete work, unfortunately, every part of the work is hidden which is of importance, and even if an architect spent the whole of his time on the job he would have to have (on a fair-sized job) a dozen pairs of eyes and a dozen personalities : so although that reading may apply to ordinary construction, where the most important part

of the work can be seen practically years afterwards, with perhaps a little opening up, in reinforced concrete work the moment the concrete is put in you lose sight of the essence of the design and the essence of the construction. If the quotation can be taken, more or less, as representing an architect's duty, it throws a very big responsibility on him. Although very close inspection may be employed, there must be hundreds and thousands of yards of concrete going in every day which is never inspected, that is, immediately before the concrete is put in, and although the steel may be originally placed in perfect position, it may be hopelessly out of position when the concrete is going in.

With regard to clauses 16 and 17 of the R.I.B.A. Form of Conditions, we were of opinion that clause 16 was not quite so covering as it might be ; because, if you take the construction of this room as an example, the builder has finished, say, the north wall ; when he gets to the south wall, we find a defect at the north end which might or might not have been able to have been seen by the architect immediately after it was executed. Perhaps a scaffolding was in front of it, or probably the architect missed it, and when the work had proceeded farther he notices the defect. We had that trouble with some steelwork, and under this clause as it originally stood the steel contractor said : "No, you only have power during the progress of the work, and the progress of that work has passed, therefore you only have power, under clause 17, as to defects after completion," which rather alters the procedure, so we altered that clause to read in this way : "The architect shall during the progress of *any part* of the works" that applies to any part of the works, and not to a particular part —"have power to order in writing," and so on. I think so far we have found this satisfactory, and it has got over several difficulties.

I am sorry for having taken up so much time, and I must again thank Mr. Valentine Ball very much for his most interesting and instructive paper.

MR. W. G. PERKINS, District Surveyor for Holborn (Member of the Council) :—Mr. President and Mr. Ball, I think, sir, in the early part of your paper you say there is no statute law which is specially

applicable to the subject in hand. I think you have forgotten the London Building Acts, the proposed regulations which would govern reinforced concrete, and the by-laws governing concrete in foundations in London, in foundations outside of London, and the construction of walls in London.

The paper is thus interesting from the point of view of the architect and contractor only, but now I want to look at it from the official point of view, and it would be very interesting if the author would express his opinion as to the contractor's position with regard to this Building Act and the by-laws I have just mentioned. Instances similar to the following have come under my notice, and these are a few notes I have made of the cases as they have cropped up. The specification furnished by the architect described certain concrete for a wall to be composed of 1 part of cement to 6 parts of aggregate. The by-law requires concrete for the work in question to be 1 part of cement, 2 parts of sand, and 3 parts of aggregate, and the local authority insisted upon the work being done accordingly. One of the conditions of the contract stated that the whole of the work was to be in accordance with the by-laws, and to the satisfaction of the local authority. In such a case can the builder, having regard to this clause, claim an extra payment for the additional amount of cement used, for the sand, and for the extra labour in mixing the concrete when composed in accordance with the by-law? that is to say, he has to handle three materials instead of two.

Then another specification I have seen contained a similar clause, but it had nothing to the effect that the local authority had to be satisfied. What would be the contractor's position now when the local authority made him comply with the by-law?

I have often come across cases where builders have contracted to do work in certain respects contrary to the Building Acts, and when I have objected I have been told, "Oh, I cannot help it; the architect's specification says that the work is to be done in this way, and if you want anything different you must apply to him." The result has been a notice which has been served upon the builder, and he has been compelled to comply with the Act and the by-laws. Sometimes

I have called builders' attention to the case of *Stevens* v. *Gourley*. I do not know whether everybody is conversant with that case, but it was a case where a contract was entered into for walls to be built of wood contrary to the provisions of the Metropolitan Building Act, 1855. When the work was done, the district surveyor took proceedings, and had the work taken down. The employer had paid a portion of the contract money, but he declined to pay the balance. The builder sued him and it was held that, the contract being one to do work contrary to law, the builder was not entitled to recover.

On the other hand, there is a case, of which I have a note, *Gebhardt* v. *Saunders,* and it was held there that where the irregularity arose out of a lawful contract, if there was no negligence on the part of the builder who has suffered the cost of complying with the notice, that builder would be entitled to recover the cost from the owner by whom he was employed, for money used at the request of the owner, or on the ground that he had been compelled to spend money for the owner on work for which the owner was legally responsible. I would be glad if the author would distinguish that case from *Stevens* v. *Gourley,* and would tell us when the contract is an illegal one and when it is a legal one. It seems to me that in either case if the architect specifies something contrary to law, the contract, so far as that goes, is an illegal one.

I have much pleasure in seconding the vote of thanks to Mr. Ball.

MR. FIANDER ETCHELLS :—Mr. President and gentlemen, the speaker refers to other problems of practical interest. I propose to speak on one or two of those coming well within the definition of concrete in its legal aspect. The paper is limited, since it has only referred to the contract side ; and, as has been pointed out, it begins by saying that there is no statute law which is specially applicable to the subject in hand. Now, then, that is an illuminating statement, because I have found scores, if not hundreds, of builders who do desire to know what the statute law requires of them with respect to concrete. In these cases the advice that is frequently given is to go to

the district surveyors, but there are only a few district surveyors, and there are very many builders, and if a distinguished representative of the Law said there is no statute law which is especially applicable to concrete in its legal aspect, surely the builders can be forgiven for not knowing what that statute law says.

Therefore I propose collecting together a few paragraphs out of the statute law and the appendices to the statute law. I should state at once that the whole of references are not claimed as being especially applicable to concrete, but some of them are specifically and definitely applicable.

Not having taken silk, I will not make any comment as to the interpretation of the laws, but just give them as they are written. These extracts will also be useful for any persons desiring to build in reinforced concrete, because, although the regulations have not yet passed into law, the builders desire to know where they stand at present, and what they can do under the existing Acts. These paragraphs will tell them.

The first is the London Building Act of 1894, the First Schedule (Preliminary). It says :—

> "The thickness of every wall not being built of bricks or stone, or other hard and incombustible substances, laid in horizontal beds or courses, shall be one-third greater than the thickness prescribed in Parts I and II of this Schedule."

I will not presume for a moment to say whether that refers to concrete or not. It may depend upon which K.C. you have engaged. Some may say that it means something different to what it says ; some might hold that it is intended to mean : the thickness of every wall being built of bricks or stone, or other hard and incombustible substances not laid in horizontal beds or courses, shall be one-third greater than the thickness prescribed, etc., and in defence of that they quote the previous Acts.

As these are not readily available, I propose reading them.

The Metropolitan Building Act, 1855, First Schedule (*a*), Preliminary Paragraph (3) :—

"The thickness of every stone wall in which the beds of the masonry are not laid horizontally shall be one-third greater than the thickness prescribed for stone walls in the rules hereinafter contained."

The Metropolitan Building Act, 1855, First Schedule, Part II, Paragraph 7:—

"The thickness of any wall of a building of the warehouse class, if built of materials other than such bricks as aforesaid, shall be deemed to be sufficient if made of the thickness required by the above tables, or of such less thickness as may be approved by the Metropolitan Board, with this exception, that in the case of walls built of stone in which the beds of the masonry are not laid horizontally no diminution shall be allowed in the thickness required by the foregoing rules for such last-mentioned walls."

The Metropolitan Building Act, 1855, First Schedule, Part II, Miscellaneous Paragraph 2, states:—

"The thickness of every stone wall in which the beds of the masonry are not laid horizontally shall be one-third greater than the thickness prescribed in the rules aforesaid."

Perhaps some advocates would hold that what is referred to in all these cases is uncoursed rubble and not concrete, but the Act at present in force, the Act of 1894, the First Schedule, Preliminary Paragraph 4, goes on to say that:—

"The thickness of any wall of a dwelling-house, if built of materials other than those before specified, shall be deemed to be sufficient if made to the thickness required by Parts I and II of this Schedule, or of such thickness as may be approved by the Council."

Then, in the Act of 1894, Part II, First Schedule, Paragraph 13, it is stated that:—

> "The thickness of any wall of a building of the warehouse class, if built of materials other than those before specified, shall be deemed to be sufficient if made of the thickness required by the provisions of this Schedule, or of such other thickness as may be approved by the Council."

Now, in addition to that there are also specific requirements with regard to concrete walls and the thickness thereof. I am quoting from by-laws made by the Council under Section 16 of the Metropolitan Management and Building Acts Amendment Act, 1878. The by-laws were made about 1891. It is stated that :—

> "The thickness of concrete walls shall be equal at the least to the thickness for walls to be constructed of brickwork prescribed by Section 12 of the Metropolitan Building Act, 1855, and the First Schedule referred to therein."

The by-laws at present require 1 to 2 to 3 for concrete in walls ; the R.I.B.A. Report requires 1 to 6, and the draft regulations require 1 to 6 ; so sometimes builders who have put up walls find themselves handicapped by having constructed a wall which does not comply with the Act at present in force. The by-laws state that :—

> "Whenever concrete is used in the construction of walls, the concrete shall be composed of Portland cement and clean Thames or bed ballast, or gravel and broken brick or stone, etc., in the proportions of 1 part of Portland cement, 2 parts of clean sand, and 3 parts of coarse material."

If builders would bear that in mind it would save them some trouble.

To prevent similar difficulties I would draw their attention to some lesser-known parts of the Act. I refer to the London Building Acts Amendment Act, 1905—statute law. The First Schedule states, *inter alia*, that the term "fire-resisting material" for general purposes includes any combination of concrete

and steel or iron. In the case of floors and roofs, the term "fire-resisting materials" includes concrete not less than 5 in. thick, in combination with iron or steel.

That is, of course, the finished thickness, and includes the thickness of the cover, or the depth of the inset of any reinforcing rods plus the effective depth of the floor-slab, plus the thickness of any cement, mortar, floating, or similar surface finish.

It will be seen from the above that the effective depth of reinforced concrete floor-slabs in fire-resisting floors is not likely to be less than about 4 in. as a minimum.

Another Act of Parliament, another statute, the London County Council (General Powers) Act, 1908, Section 17, Sub-section 3, provides that :—

> "The Council may in any case in which they think fit to do so, consent to any such building, or part of a building as aforesaid, being divided (wholly or in part) horizontally by floors to be constructed in such manner, and of such materials, and in all other respects as the Council may require or approve, and in such case such floors shall for the purpose of this Section be deemed to be division walls."

That raises the question, When is a floor not a floor? (When it is 6 in. thick?) Or is it a wall and a floor simultaneously?

The Regulations with regard to applications under Part III of the London County Council (General Powers) Act, 1908, as to additional cubic extent, Paragraph 5, Sub-Paragraph (XVI) states that in certain classes of buildings the divisions or cells formed by the horizontal separations shall not exceed 250,000 cubic feet, and every floor shall be of the thickness required by the Council, such thickness not being less than 6 in.

THE PRESIDENT :—Mr. Valentine Ball says no reference is made there to concrete. Is it meant there that concrete can be used for 6 in. thick horizontal floors?

Mr. FIANDER ETCHELLS :—In effect, yes.

THE PRESIDENT :—That is the intention?

MR. FIANDER ETCHELLS :—That is so. I am bringing these points forward because they are points which have time and time again occasioned difficulties to builders who have got the building up first and found out about the statute law afterwards.

MAJOR H. S. ROGERS, R.E., Surveyor of Prisons, M.C.I. :—I am afraid I came unprepared to say anything on this subject at all. I am in the position of getting free labour and carrying out concrete work by prisoners, so that I have not any difficulties with regard to contractors or sub-contractors at present.

I came in the hope of learning how to avoid difficulties if I do have to carry out reinforced concrete by contract.

MR. OSBORN C. HILLS, F.R.I.B.A., District Surveyor for the Strand (Member of Council) :—I have not come prepared to say anything at all, but I should just like to say a word with regard to Mr. Etchells's view. I think Mr. Etchells's reference to the 1855 Act might very well stand on one side. It was obviously the intention at that time, when concrete was scarcely known, that all those references are to uncoursed rubble or random rubble walls. I think it is rather asking Mr. Valentine Ball to go a long way back to give any legal decisions on such things as that. Concrete, and especially reinforced concrete, was scarcely thought of at that time, and the references are all to uncoursed or random rubble.

There was another point I should like to hear from the lecturer, what he thinks is the position to-day of the architect who specifies reinforced concrete floors he cannot supervise. There is a floor not a mile away from here with a certain amount of steelwork. The proper amount of steel was provided for. At the end of the job a certain amount of steel was carted away, and we did not know how we came to have the surplus. We have searched and have discovered at last that there is a whole bay of concrete, about 17 ft. span, and not one iota of the steel was there. Is the architect responsible for that? Poor man! he knows nothing about it. He specified it, he had a clerk of the works; there was somebody there who certainly would not

have allowed it if he had known it. Now it has been discovered, it is going to be put right. Had it not been discovered, and an accident happened, surely the architect would not be responsible for it. But I am only asking for information.

THE PRESIDENT :—Is that standing out now, Mr. Hills?

MR. HILLS :—No, suspicion was aroused and search was made in one or two places ; a certain hole was made which should have cut a steel rod ; a steel rod was not cut ; it was intended to cut away till we came to the steelwork, but we never came to it.

THE PRESIDENT :—Had the struts been removed?

MR. HILLS :—Yes.

THE PRESIDENT :—What span did you say?

MR. HILLS :—About 17 ft.

THE PRESIDENT :—Seventeen feet span, and what was the thickness?

MR. HILLS :—I don't remember, but probably $5\frac{1}{2}$ to 6 in. It would have come down soon.

MR. FIANDER ETCHELLS :—I should just like to say one word to prevent any confusion at a later date. I just want to say that I am in agreement with Mr. Hills as to his interpretation of the Act of 1855. Personally I believe that the paragraph in the 1855 Act referred to uncoursed rubble.

Whether the preliminary to the first schedule in the London Building Act of 1894 is intended to cover something different from the Act of 1855 is a question which I leave to be settled by the luminaries of that profession which has the greatest respect for words and precedents.

MR. HERBERT SHEPHERD, A.R.I.B.A., M.C.I. :—I think, Sir, as I totally disagree with that statement of Mr. Etchells, I had better rise and say so at once, but in the first place I have a very pleasant duty to discharge in thanking Mr. Valentine Ball most heartily for his very interesting paper. With regard to what

Mr. Etchells said, I do not agree either with him or Mr. Hills, because, if they go back to the fifties, they will find I think that actually some of the merchants dealing in concrete to-day at that time advertised that they were building in a very large way all over the country with the new material, as they called concrete then. There were, in the North of England particularly, concrete houses being built in the fifties. Many of the clauses of the 1855 Act originated out of a request by the Government of 1850 to the Institute of British Architects to assist them in framing what was then called The Metropolitan Buildings Bill, and it was mainly with the assistance of the committee of members of the Institute that these draft regulations were first brought into being. I might mention another interesting point in regard to this, and that is that at the inaugural meeting in 1835 the very first medal that was ever offered by the Institute of British Architects was one for an essay "On the Nature and Properties of Concrete," so that I do not agree that the '55 Building Act, and the men who framed those regulations, had only in mind loose rubble, or masonry walls. I believe they had at that time full knowledge that concrete was being used. Again, you must remember that the regulations with regard to the admixture of aggregates in concrete apply not only to walls but also to foundations ; and it does seem an anomaly to me that at the present day, in spite of the revisions which the Building Acts have received, owing to the progress of construction, that it is still possible for one to put only 9 in. thickness of concrete under a wall say 80 ft. high, to legally conform with the Building Act.

MR. FIANDER ETCHELLS :—Quite right ; I have nothing to say to that. Mr. Shepherd has quite misunderstood me. All that I said was that I agreed with Mr. Hills as to his interpretation, and the only interpretation I have ever heard as to the three paragraphs I have read out, namely, that those three paragraphs refer to uncoursed rubble. Most certainly in 1850 they knew about concrete ; they did two thousand years ago.

MR. PERKINS :—I think the point really is this, is it not, Mr. Etchells (if I may speak again, Sir) :

Does the present by-law require a concrete wall to be one-third greater in thickness than it would have to be if it were a brick wall?

MR. ETCHELLS :—That question might most properly be addressed to the legal luminary here this evening.

THE PRESIDENT :—As Mr. Valentine Ball stated he was wishing to get away early, and very likely before the discussion was over, he is wishing to make short replies to the several speakers. We will continue the discussion after he has left, and his replies to the various speakers will appear in the Proceedings. I will now ask Mr. Valentine Ball to reply to the discussion as far as it has gone.

MR. VALENTINE BALL :—Mr. Chairman and gentlemen, I am much obliged by your courtesy in allowing me to deal very briefly with one or two of the points which have been raised. And first with regard to the very interesting points put by Mr. Scott as to the position and the liability of the specialist. He instanced five different methods of employing the specialist, and so far as I could put them down, in the second of them the specialist was a person employed by the architect to carry out the design. Well, in that case I should say that the responsibility of the design would rest with the architect. He would have to select the specialist in whom he had confidence and trust. In doing that he would have to perform his duty to the employer. If the specialist made some stupid mistake or designed the work in such a way that it would not stand the strain which he knew it was intended to stand, then I should think the fault would lie with the architect.

As to the liability of the contractor for the specialist, that has been to some extent foreseen in the R.I.B.A. Form. If you will look at that form, you will find that the contractor is entitled to object to the employment of any specialist who will not enter into a contract with him indemnifying him from the consequences of the specialist's fault and delay. That, in some measure, does afford protection to the contractor.

As to the general question—Who is liable for a fault in design? So far as I can recollect the decisions on the point, it appears that if the employer engages a contractor to use a particular kind of patent roofing, and says, "Now, you must use that and no other," and the patent roofing turns out to be wholly incapable of keeping out the wet, then the responsibility is not upon the contractor. He simply does what he is told. Where the designs of the engineer or architect, as worked out by the specialist, are faulty, then, again, I suppose the liability would be on the engineer or the architect. It appears to me from what various speakers have said there are various kinds of specialists in reinforced concrete. I was not referring to their capacity. There are some who design, and some who merely carry out the designs of others, and as to the exact liability I would take the opportunity, when the speeches come before me in print, of going into it a little more closely and letting you have a more definite answer.

With regard to the question raised as to the inspection by the architect of reinforced concrete when it is in the laying, it appears to me that the modern class of building contract does not provide exactly what the duties of the architect shall be. It appears to me utterly unreasonable to suppose that the architect must be there when every piece of steel is being put into place, and I do not suppose any court of justice would hold that that was the duty of the architect. The observations of the judge in the Scotch case to which I refer in my paper could hardly be held applicable to the supervision of the laying of reinforced concrete. If, however, the architect is liable to see that all the steel is used, I suppose he must protect himself by insisting that more than one clerk of the works shall be employed, and that the clerk of the works shall be careful to exercise due diligence in supervising the contractor.

Mr. Perkins raised a question as to the observance of by-laws by the builder. He assumes the case where the contract and specifications are such that if strictly complied with they will not comply with the by-law. Now, the R.I.B.A. Form expressly provides for that by Clause 5. If you look at that, you will find that

the duty of complying with by-laws, past, present, and future, is thrown upon the builder. If he finds in carrying out the work that he cannot comply with the by-law if he complies with the specifications, he is entitled to give notice to the architect and say, "I must comply with the by-law," and then, if he complies with the by-law, he is entitled to treat everything—all the expenses and so forth which he incurs in so complying—as an extra under the contract. Such an extra is dealt with in accordance with Clause 13 of the Form, just as other extras are dealt with. I may say that I am not here quoting my own opinion. It was all expounded in a very recent case in the High Court of *John Barker* v. *The Hurlingham Club,* where the whole question of extras was gone into, and that was instanced as a particular case where, notwithstanding the opinion of the architect, the builder is entitled to treat compliance with by-laws as an extra to comply with them, and then charge it as an extra.

AN HON. MEMBER :—Not necessarily an extra, sir, is it? It may be an omission.

MR. VALENTINE BALL :—Quite right, sir ; it might be an omission.

THE HON. MEMBER :—Has the architect power to enforce that omission?

MR. VALENTINE BALL :—Apparently he has, and all omissions are dealt with under Clause 12.

THE HON. MEMBER :—But in the case of a contract not under the R.I.B.A. Clause?

MR. VALENTINE BALL :—The question would then depend on the terms of the contract.

THE HON. MEMBER :—For instance, years ago, the man I was articled to never used those clauses.

MR. VALENTINE BALL :—I am afraid I cannot answer a general question unless I have the terms of the contract before me. I merely gave the answer, assuming you used the R.I.B.A. form. Even a lawyer sometimes likes to talk with the document in front of him.

Now, with reference to the interesting points raised

by Mr. Etchells, I am very glad he has drawn my attention to the fact that concrete is in some way alluded to in certain Acts of Parliament, but it does not seem to me that the manner in which it is alluded to and the provisions of those Acts have any very material bearing upon the subject of my paper this evening. But still, I am very glad to be reminded that, in point of fact, it is referred to in the London Building Act, 1905.

As to the Act of 1855, I rather think that that was repealed and supplanted by the London Building Act of 1894. I think there is one thing we are all agreed upon: that whatever might have been thought of concrete in 1855, nobody heard very much about reinforced concrete at that time, so that I do not think that that Act, at any rate, is of very much assistance.

Before I conclude I would just like to tell Mr. Perkins that if he had stopped at the case of *Stevens* v. *Gourley* I would have been prepared to answer him, because I remembered that case and knew about it. But he has mentioned another case of *Gebhardt* v. *Saunders*, which, he says, is in conflict with it. I shall take the opportunity of looking at those two cases before I conclude my reply, and try to explain the difference between them.

Gentlemen, I thank you very much, not only for the courteous attention which you have paid to a very dry and dull paper, but also for the very apt and informing criticisms which you have made upon it. Those criticisms will be of the very greatest possible interest and use to me in dealing with this subject in its legal aspect.

[Since replying in the above terms I have looked at *Stevens* v. *Gourley*, 7 C.B.N.S. 99, and *Gebhardt* v. *Saunders*, 1892, 2 Q.B. 452. The former case decides that a contract for the erection of a building in contravention of the provisions of the Metropolitan Building Act, 1855, cannot be enforced. The latter decided that a tenant from year to year was entitled to recover from his landlord sums which he had been compelled to expend on sanitary improvements under The Public Health (London) Act, 1891, Sec. 4, although the usual notice had not been served on the

owner of the premises. The two cases do not appear to conflict; they relate to different matters.]

MR. W. H. LASCELLES, M.C.I. :—Mr. President and gentlemen, the lecturer made a remark at the latter end of his speech just now as regards reinforced concrete not being very well known in 1850 or 1860. Well, my knowledge of reinforced concrete goes back very nearly to that date, and I have been accustomed to the use of it for a considerable period—not quite all that time.

Another gentleman made a remark about a horizontal floor dividing a building which should not exceed 250 feet.

MR. FIANDER ETCHELLS :—250,000 cubic ft.?

MR. LASCELLES :—That is quite right. I have had experience of that. I did put in a horizontal floor to reduce the cubical area of a building to that amount, and after I had done it and was prepared to open it I was compelled by the County Council to put a vertical wall dividing it again. The floor was composed of concrete of the regulation 6 in. thick. Well, I was prepared to fight the question, but was really advised not to do so.

I have had a good deal of experience with the County Council and others regarding the thicknesses, etc., of the concrete, reinforced and otherwise, and up to the present time I must acknowledge that I have been beaten nearly every time, more particularly regarding the thicknesses required for reinforced concrete. It has always been held that it must be not less than the by-laws of nearly every town and city that I have had to do with prescribe. It has always been held that no wall must be of a lesser thickness than their by-laws stated, whether it was bricks, reinforced concrete, or otherwise, and that, for the last twenty or thirty years, I think, has been the reason that reinforced concrete has been not more universally used.

I have tried very hard in many instances to build houses with walls reinforced 6 in. thick, and perhaps less than that some of them. I have built as thin as $1\frac{1}{2}$ in. I dare say you have heard of them. I might say this, that after thirty-five years' experi-

ence the houses that are built with reinforced concrete, certainly not exceeding 2 in. thick, at the present moment are as good as the very first day they were put up, and they can be seen by any of our members.

I thank you for allowing me to make these few remarks on the subject of reinforced concrete.

MR. PERCIVAL M. FRASER, A.R.I.B.A., M.C.I.:—I am afraid I have not had time to read the paper, Mr. Chairman. I am very sorry I have nothing to say.

MR. HORACE CUBITT, A.R.I.B.A.:—I should like, if I might, to raise a point with Mr. Fiander Etchells and Mr. Perkins. I quite agree with them as regards the criticism that there is a very considerable statute law in regard to this subject. Even then they have not gone far enough. Mr. Fiander Etchells has quoted many Acts, going back to the 1855 Act, but he has left out in his quotation two very important Sections. One is Section 82 of the 1894 Building Act, which says that where a building is of such a nature that the ordinary provisions of the building law are inapplicable, a person may go to the County Council, and this authority may approve any construction it pleases. That is the only Section under which special structures like silos can, at the present time, be erected in London.

MR. PERKINS:—He must show that the rules are inappropriate as well. These are the words of the Act.

MR. CUBITT:—The fact remains that the Council have approved several reinforced concrete silos under this Section.

Another Section that specially affects Mr. Perkins is Section 78 of the Building Act. That Section says that, practically notwithstanding anything in the Act, public buildings must be constructed in such a manner as may be approved by the district surveyor. If you put up a reinforced concrete floor in a public building, the district surveyor quotes that Section against you, and says, "I want to supervise the construction." But there is another phase of the operation of the Section on which I do not see eye to eye with the

district surveyors, where, for some reason best known to themselves, they place a limit to their powers under the Section. The Section says that they can approve any construction they please. Practically what they do is to read the Section as giving them power to require any extra construction they please. Of course, they are quite entitled to read it in any way they like. The only thing I wish to suggest is that Section 78 gives a right of appeal to the Tribunal of Appeal, and it is quite possible that the tribunal might allow the erection of a public building constructed throughout of reinforced concrete.

Then, I would just like to refer to this question of the thickness of concrete walls. I do not know whether the reader of the paper quite understood the thing we were driving at. It is this: the Building Act says a wall of certain material not in horizontal courses, and so on, must be one-third greater than a brick wall. The by-laws say—we need not go back to the Act of 1855—that a concrete wall must not be of less thickness than a wall required by the Schedule of the 1855 Act. The 1894 Building Act says that a reference to a Schedule of the 1855 Act in any Act or by-law is to be read as a reference to the corresponding Schedule of the 1894 Act, and, reading all those things together, I think you can make out a very good case for the contention that a concrete wall which is constructed with shuttering carried up horizontally, and the concrete put in in horizontal beds, can be constructed of a similar thickness to a brick wall. It is not perhaps a very practical question, because you want to build walls of less thickness than brick walls, but I think a very good case can be made out for that suggestion.

MR. FIANDER ETCHELLS:—To make it complete I might draw attention to the fact that my friend Mr. Cubitt has left out another section. Section 203 gives power to the Council to sanction reinforced concrete work in connection with electricity buildings, and in those cases they have done so, not lately, but as long ago as 1900 and 1901, as well as at present.

MR. CUBITT:—May I cap Mr. Fiander Etchells' remarks by saying that Section 207 provides for works

of alteration to all classes of buildings being carried out in any desired material, subject to the consent of the Council.

MR. FIANDER ETCHELLS :—Practically all Sections of the Act are related in some way to the concrete.

MR. J. S. ALFORD, M.C.I. :—Sir, I would like to ask if Mr. Valentine Ball will receive any written statement which one could send in before he replies.

THE PRESIDENT :—Yes, he promised to do that.

MR. J. S. ALFORD :—Because I happened to be concerned with *Pearson* v. *The Dublin Corporation*, and I think the facts are not quite clearly stated in the paragraph and I would like to have them put right. There is a point of interest earlier which I should like to refer to, and that is the case of *Adcock's Trustee* v. *Bridge R.D.C.* Now that is a case I know very well. Mr. Ball there puts the effect of a certain clause in the contract, and for an engineer to appreciate the effect of Mr. Ball's remarks, I think it should be said that that contract specified stock brickwork in sewer manholes 9 in. thick for a considerable head of water. When the work was constructed the contractor deposited a sample brick. That sample was accepted, and the work was put in substantially in accordance with the sample. Then it was found not to be watertight, and the Council withheld the contractor's money, so that reading the specification in the light of those facts perhaps the inferences were not quite as Mr. Ball drew them.

THE PRESIDENT :—Would anybody else like to make a few remarks?

MR. PERKINS :—Mr. Cubitt's argument is that under Section 78 the district surveyor has power to sanction the construction of a public building in any way he pleases ; that is to say, he may approve of the construction of a theatre or a church in brown paper. Well, I do not think that was the intention of the Legislature. It is not the view I take of the Section, although I must admit I am in conflict with most of my

colleagues on that point. I say that Section 78 means this, that the district surveyor is to see that all the rules of the Act are carried out, but if, in addition, he thinks something else is necessary to ensure the stability of the building, he is empowered by that Section to ask for it. If you do not take that view what becomes of Section 80, for instance, which regulates the width of corridors and doorways in churches and chapels and other places of public assembly. If the district surveyor has the power from Section 78 to dispense with all the rules of the Act, he can dispense with that one. If you turn to Section 68 you will see that it says that in every public building the floors of the lobbies, corridors, and landing, and the flights of stairs shall be in fire-resisting materials carried by supports of fire-resisting materials. If Section 78 dispenses with all the other Sections of the Act, it will dispense with that section, too, and the district surveyor can approve a floor of ordinary boards and wooden joists! It comes to this: if you are to give effect to Sections 68 and 80, you must give effect to all the other Sections of the Act. That is the only sensible way of looking at it.

MR. CUBITT:—Would the Chairman like to see the Section and read it to the Meeting—Section 78? It seems to me it is plain English.

THE PRESIDENT:—"Construction of Buildings."

> "78. Notwithstanding anything in this Act every public building including the walls roofs floors galleries and staircases (and every structure and work constructed or done in connection with or for the purposes of the same) shall be constructed in such manner as may be approved by the district surveyor or in the event of disagreement may be determined (by the tribunal of appeal) and save so far as respects the rules of construction every public building shall throughout this Act be deemed to be included in the term building and be subject to all the provisions of this Act in the same manner as if it were a building erected for a purpose other than a public purpose."

MR. PERKINS :—I would call attention to those last words.

MR. CUBITT :—Is that as regards construction?

THE PRESIDENT :—Yes.

MR. PERKINS :—Would you mind reading the words of Section 68.

THE PRESIDENT :—Wait a minute till I have finished this.

> "No public building shall be used as such until the district surveyor or the tribunal of appeal shall have declared his or their approval of the construction thereof.
>
> "After the district surveyor shall have so declared his approval or shall certify that it has been constructed as directed by the tribunal of appeal any work affecting or likely to affect the building shall not be done to in or on the building without the approval of the district surveyor or such certificate as aforesaid."

Now, you say you want Section 68 read. I wish they would give us a number of back references; it would save a lot of trouble.

MR. PERKINS :—It would.

THE PRESIDENT :—You will remember that, Mr. Etchells, will you not?

> "68. In every public building and in every other building of more than one hundred and twenty-five thousand feet (in cubical extent) and (which is constructed or adapted to be) used as a dwelling-house for separate families the floors of the lobbies corridors passages and landings and also the flights of stairs shall be of fire-resisting material and carried by supports of a fire-resisting material."

MR. PERKINS :—Now, I would ask whether Section 78 waives that Section. Section 78 is the one which gives the district surveyor a certain option. Section 68 is mandatory; so is Section 80.

MR. ALBAN SCOTT :—You have allowed an amount of latitude to-night ; will you extend it to me for one second?

THE PRESIDENT :—I will.

MR. ALBAN SCOTT :—I would seriously suggest that as this matter with regard to the Building Act has been discussed so enthusiastically by gentlemen to-night we should have, if not a formal an informal meeting for discussing the subject. I would suggest also, if I might, why not a temporary licence, put it up in reinforced concrete and let the Council pull it down?

THE PRESIDENT :—I think it would be very interesting if we had a paper read here upon the London Building Act later on. Would anybody else like to say anything?

MR. ALBAN SCOTT :—A discussion or a paper?

THE PRESIDENT :—A paper. Now, gentlemen, as nobody wishes to say any more I will close the Meeting with a few remarks. In reference to the question which has arisen as to sub-contractors, I think it would be a very good thing if all architects and engineers would simply adopt what is carried out by the London County Council, namely, that when tenders are submitted the principal contractor has to submit to them the names of all the sub-contractors, not only as to the work he sub-lets but also as to the manufacture of steel, so that they can approve beforehand the sub-contractors that he is going to employ. I know in some cases that they have not approved of certain sub-contractors, and the contractor then has to get another one to do the work. I think if this is done and approved in the first instance it is only fair to assume that the sub-contractor, before he enters into any agreement or into any sub-contract with the main contractor, is conversant with the conditions of the contract, and also the specification, and I think that would save a lot of trouble, because I know at the present time in reference to many sub-contractors that they never enter into a proper contract at all ; it is very often done simply by a letter. Sometimes

it does not go that far, and when accidents do take place it generally ends in legal proceedings unless they can come to some amicable arrangement.

With reference to the liability of sub-contractors, there is a case that I have in mind—it happened about four or five years ago—of a roof that was put up supposed to have been in reinforced concrete. It had a span of about 18 ft. and was 7 or 8 in. thick, and after being up for about eight years it suddenly started to deflect, and this deflection went on to such a serious extent that in three months it was down over 3 in. Investigations were made, and it was found that what reinforcing was put in was all on the wrong side; it happened to be on the top side of the slab. In the first instance the walls were good. The roof trusses were practically tying the walls together and the floor was acting as a flat arch. After many years the roof principals became loose, and in heavy gales they started to hammer, and there is no doubt about it the walls moved. The slab then acted as a beam; the concrete could not take up the tension, and if it had not been attended to there is no doubt it would have fallen.

Now, in this case the public authority that had charge of this building called upon the sub-contractor and compelled him at his own expense to pull down and reconstruct the whole roof. Whether they could do that legally or not is another matter, but still, it was done, and whether it was because the sub-contractor thought it better to bear the loss than risk the exposure in the courts of law is a matter I do not know. At any rate, since then the firm, which was one of the oldest contractors in the country, has ceased to exist.

There is a very good method adopted by some architects and engineers with reference to sub-contractors, and that is that when a certificate is issued that includes a certain amount for the sub-contractor, the architect or the engineer refuses to grant another certificate until such time as the main contractors produce receipts from the sub-contractor that he has been paid the amount that has been certified for. If this be done and carried out in every case, and a clause put in the specification to that effect, it would save

a great amount of trouble and possibly any quibbles hereafter.

Some say an architect or an engineer has no right to do such a thing, but personally I think he is justified in doing so, as it saves a lot of trouble ; and in case the main contractor or builder becomes bankrupt, then the sub-contractor will afterwards be paid by the building-owner, and if there is no clause in the specification, then, of course, the poor unfortunate subcontractor has to bear the brunt of it and lose his money, and also all the work that he has executed.

The case cited of *Thorn* v. *Mayor of London* I do not think is exactly clearly stated. Mr. Ball said it was a fact that the foundations for the caissons were exceedingly difficult to obtain. As far as my recollection goes of an arbitration case I was engaged on in 1878, it was lost on that very precedent of *Thorn* v. *Mayor of London*, and as far as my memory goes, I believe it was due to the fact that the engineers, in designing the caissons, made them about two to three feet too short ; the consequence was that when they were sunk down to their proper level an exceptionally high tide came and flooded them out. They had, therefore, to increase the height of the caissons. The action was brought, and it was held that as the whole of the work was contracted for in London the contractor ought to have made himself conversant with everything that was taking place in the matter of the tides, and it was very easy for him to find out, which he did not do. With regard to the case which I was engaged upon for three months, the contractors lost their action on that precedent. It was a case of a pier a mile long, where they had taken a level on the beach and made a sounding at low water a mile out, drew a straight line between the two points, and then wriggled in the line with a ruling-pen. The whole of the foundation was rock. The piles were all screw piles, and after the pier was constructed for 150 ft., piles which were intended for 2,000 ft. out were being used. The Government were notified that there would be claims for extras: These they refused to sanction and the case went to arbitration, and it was lost upon this precedent of *Thorn* v. *The Mayor of London*.

Now, exactly the same thing might take place in any

reinforced concrete pier or structure of such a nature where a contractor had not time to make the necessary investigations because the time given to him to tender might be too short, and yet if he found afterwards upon investigation that the facts were not correct, he had no claim. If that precedent is allowed to remain, then he is wholly responsible for all the loss he may be put to and for others' mistakes.

Other questions have been raised here of defects after completion. I know of a failure of reinforced concrete which in its descent brought down a lot of other walls with it, and in regard to every brick wall that was examined, it was found that though it was supposed to have been put up in brickwork and cement, yet three weeks afterwards the pointing only had set hard for a quarter of an inch and in the interior the mortar was as soft as it was when it was put up, due entirely, in my opinion, to a dirty aggregate. Here is a case which the architect would not notice. The clerk of the works ought to have seen that a dirty aggregate was being employed and prevented the same from being used. It was only an accident that disclosed the defect. The question is, who, then, become responsible, supposing the failure had taken place through the dirty aggregate—the builder or the reinforced concrete contractors?

Mr. Lascelles has enlightened us about concrete houses. I have a clear recollection of seeing concrete houses which had been put up in Australia fifty years ago. There lime was used, and the last time I was out there—I left about 1880—I have a clear recollection of seeing some of these houses then standing and in perfect order.

The next meeting will take place on January the 30th, when Mr. J. S. Owens will read a paper entitled "The Settlements of Solids in Water and its Bearing on Concrete Work."

The meeting then terminated.

CORRESPONDENCE

Mr. J. S. Alford :—In order that the author's reference to the case of *Pearsons* v. *Dublin Corporation* (a case with which my firm was concerned) may

be quite clear, it is necessary to state that the employer in that case did not "seek to put upon the contractor the responsibility of estimating how much material will be necessary to complete the work." All additional excavation that was made and concrete that was used was paid for to the extent of many thousands of pounds and there was never any dispute on this point. The subject-matter of the action was the cost of pumping water from the excavations. The defendants' case was not even opened before the jury except that counsel applied for a non-suit, which was granted.

The sole question before the House of Lords is stated clearly by Lord Halsbury thus: "Was the Chief Baron right in withholding the question from the jury?"

It would therefore appear that the case of *Pearsons* v. *Dublin Corporation,* although very interesting from many points of view, has only a limited bearing upon the statement with which the author opens this section of the paper.

MR. A. ALBAN H. SCOTT :—With reference to Mr. Valentine Ball's paper on "Concrete in its Legal Aspect," there were many points I had wished to raise in the discussion, but did not want to take up too much time.

The following points have occurred in actual practice and I think are sufficiently serious to come under review :—

Where the contractor executing the reinforced concrete work gave instructions to the reinforced concrete specialist to prepare drawings, the contractor served notice on the specialist that he was not to supply the architect with copies of any of the plans. This refusal occurred after some question as to the stability of the work arose and the architect had mislaid the original copy supplied to him. This I venture to suggest is a most dangerous position for an architect to be placed in, and means that the architect or the building owner is compelled either to sue for discovery of documents or that the builder is acting within his legal rights, and the architect although responsible for the work had not the very necessary information in front of him. The complications arising from such a position are far too numerous to enter into.

A further point also arises when certain particulars are required from the person or firms who made the original calculations and prepared the designs, in the case where alterations are required to the building after completion.

In this case can the architect or building owner demand such information as may be necessary for the purpose of carrying out any alterations or altering the disposition of heavy dead loads which the structure may be subjected to in the revised arrangements?

There is one further point which I think requires some clearing up in connection with the R.I.B.A. Conditions of Contract. In Clause No. 20 it states, "all specialists, merchants, or tradesmen or others executing any work or supplying any goods for which prime costs, prices, or provisional sums are included in the specification . . . are hereby declared to be sub-contractors employed by the contractor." When these conditions were drawn up no such thing as a concrete specialist was in existence, at any rate in England, and it was never intended that this clause should apply to a concrete specialist, more especially when a concrete specialist is simply designing the work either for the contractor or for the architect, but it would appear that if this point were raised in a law case that further complications might ensue owing to the inclusion of the word "specialist" in this clause.

I am strongly of opinion that the position and responsibility architects are forced into when dealing with reinforced concrete work in the various methods employed to-day is so serious that the Council of this Institute should take steps to have the whole matter thoroughly cleared up as to the respective responsibility incurred by the building owner, the architect, consulting engineers, the designing concrete specialist, the concrete specialist who designs and supplies the materials and executes the work, and also all these parties in relation to the general contractor.

I would suggest that the council might formulate certain questions and submit them for counsel's opinion and the replies published in the Journal would be of inestimable value to the members.

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